Joint Centre for Mesoscale Meteorology, Reading, UK

Met Office Unified Model data, diagnostics, graphics programs and other observational data available from the JCMM through the aegis of the Universities Weather Research Network (UWERN)

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1 SERVICES PROVIDED

The Universities Weather Research Network (UWERN) is a collaboration whose mission is to

> ... harness expertise from within UK Universities, and expolit facilities from within Universities, Research Institutes and the Meteorological Office to advance the knowledge, understanding and prediction of atmospheric behaviour on regional and smaller scales.

UWERN aims to encourage the widespread use by the academic community, in research, of the Meteorological Office's Unified Model and observational data. The main aim of this report is to stimulate such use.

Under the UWERN Core Strategic Component (Shared support facilities), we, the authors, Peter Panagi and Ed Dicks, intend to provide the following support to members of UWERN

1. Making available archived/current Unified Model (UM) data products from the Met. Office's central archiving facility. Data will be either in IEEE or ASCII formats.

2. Making available Satellite, Radar and Sferics (lightning) data, either data held locally at JCMM or from the Met. Office's central archiving facility. Data will be either in IEEE or ASCII formats.

3. Helping with the installation and running of the Met. Office Unified Model on Cray and Silicon Graphics platforms. At present, neither of the authors has experience in configuring and running the UM on any other platforms, but the Met. Office's internal support team can provide support for running the UM on DEC-Alpha and HP platforms.

4. Helping to set up UM jobs via the Unified Model User Interface on your local workstations

5. Providing a readily accessible graphics utility for viewing UM data, either from the archives or from a user's own UM output.

6. Providing post-processing diagnostics derived from basic UM output data and programming advice on potentially useful new diagnostics.

7. Providing general programming support and advice on obtaining and using other data, such as upper air and surface data that can be obtained through the British Atmospheric Data Centre (BADC).

8. This document and software supported can be obtained also from the WWW, solely for UWERN collaborators, under

   http://www.badc.rl.ac.uk/data/uwern
   http://www.met.reading.ac.uk/Links/weblinks/uwern.html

2 ABOUT THIS DOCUMENT

This document is divided into 3 main parts.

1. In the first part of this document (Section 3), we lay out simple flow diagrams to direct you to the information that you will require to attack your research problem. Of course there will not always be a unique solution, but you will at least know what to look for initially.

2. In the second, major part (Sections 4 onwards), we outline all the main kinds of data and supporting software that is available, whether we support it directly or not, and if not, how to go about getting what we don't support.

3. In the final Appendices (A-F), we include detailed documents on the Unified Model and a more detailed description of the software used to manipulate UM and observational data.

3 FLOW CHARTS DIRECTING YOU TO DATA

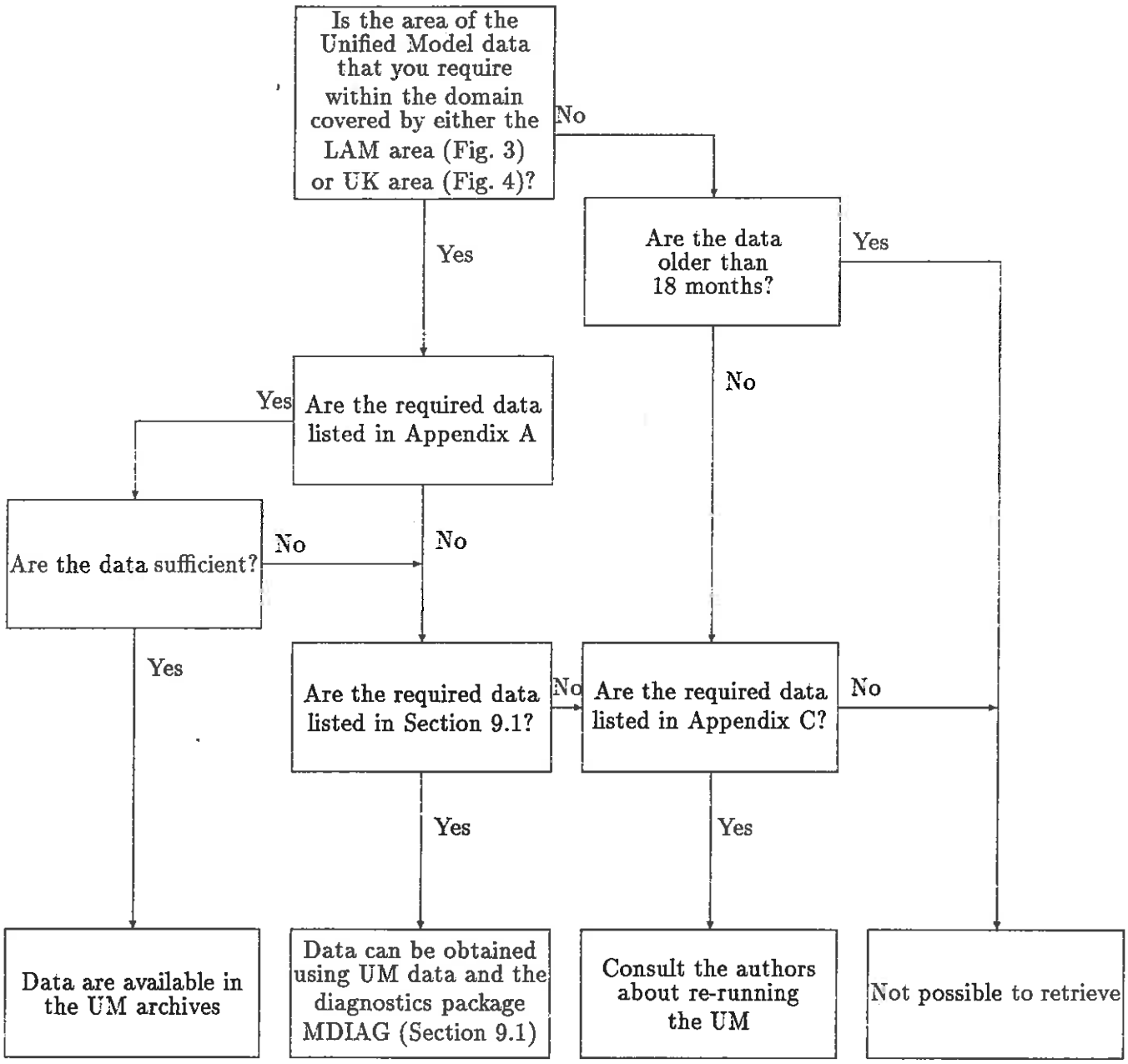

Figure 1: Flow chart showing routes for requesting UM data.

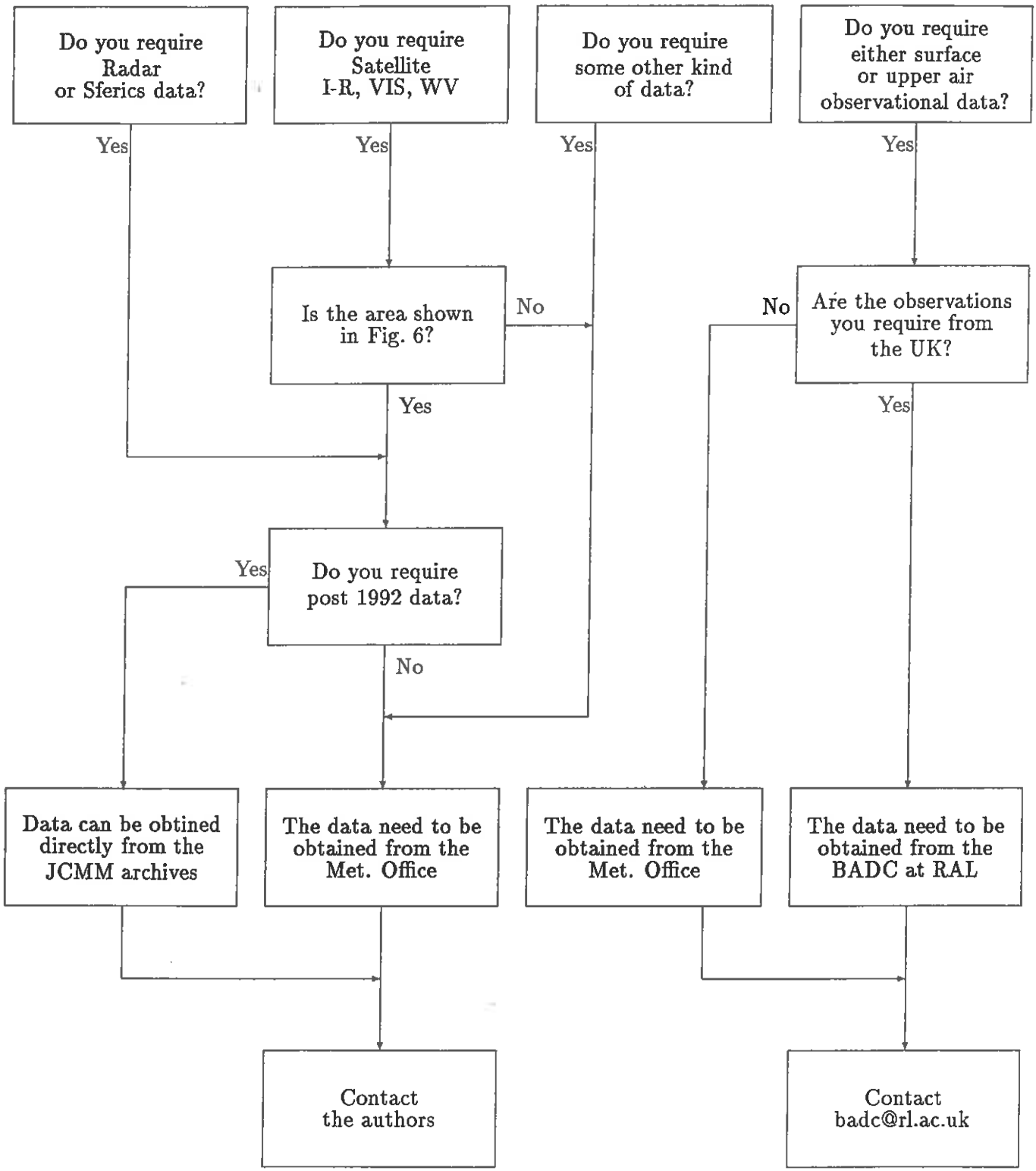

Figure 2: Flow chart showing routes for requesting observational data.

4 THE UNIFIED MODEL

4.1 A brief overview

We present here a brief introduction to the way the Unified Model (UM) is run operationally at the Met. Office, i.e. on a daily basis to produce forecasts. We also include some Met. Office internal documents accompanying this report giving more detailed overviews. Also accompanying this document is the main Unified Model user guide giving details on all aspects of the UM. The accompanying documents are

- Atmospheric Formulation and Numerical Weather Prediction ed. Alan Dickinson
- The Unified Model ed. Alan Dickinson
- Numerical Weather Prediction - press release
- Progress Report on the Global Data Processing System 1996, ed. Rick Rawlins
- Unified Model user guide

Since 1991, and until Autumn 1997, the UM has been run at three resolutions

- **Mesoscale** 92x92 horizontal grid points and 31 vertical levels Horizontal resolution: 17km.
- **Limited area (LAM)** 229x132 horizontal grid points and 19 vertical levels. Horizontal resolution: 50km.
- **Global** 288x217 horizontal grid points and 19 vertical levels. N-S resolution $\simeq$ 93km, E-W resolution $\simeq$ 139km at the equator and $\simeq$ 89km at 50N.

Computations at both the UK Mesoscale and LAM resolutions are on a rotated lat/long grid, where the pole has been rotated so that the centres of the grids are roughly equatorial, and the region of interest has an even grid spacing.

Vertical resolution in all models is on η levels, η being a numerical coordinate that is linearly related to the surface pressure at a given point. The advantages of using these corrdinates are that the bottom levels follow the terrain closely, useful for realistic boundary conditions, whereas the upper levels are more like uniform pressure surfaces. The resolution is greatest near the surface where the model variations are expected to be large.

The three models run consecutively on the Met. Office Cray, a C-916. The global model produces boundary conditions for the LAM, and the LAM boundary conditions for the UK Mesoscale runs. Figures 3, 4 show the domains covered by the LAM and UK Mesoscale areas respectively (both produced using JPLOT, described in Section 10.1).

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Master of coloured pages.

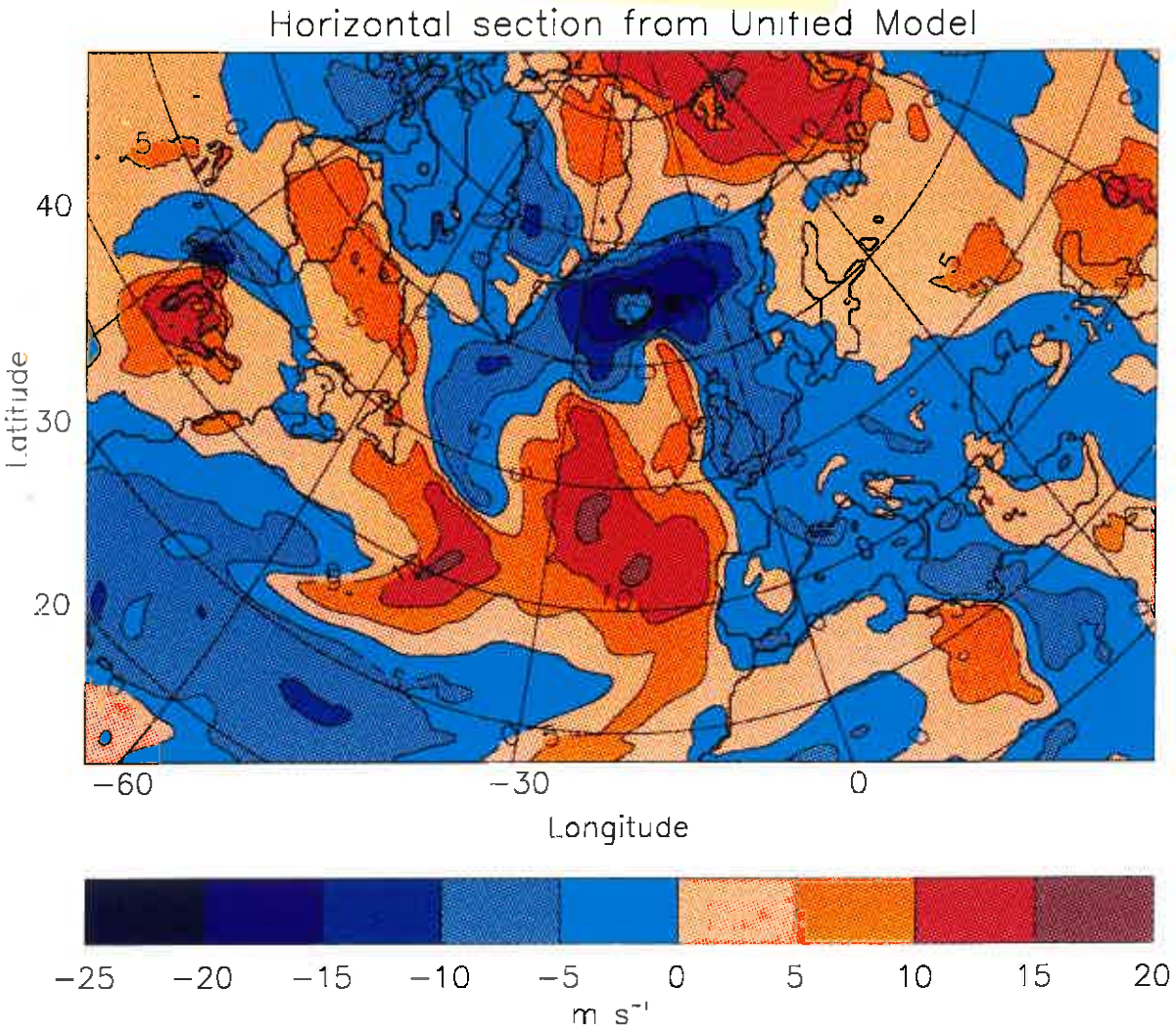

Figure 3: A horizontal section from the Limited Area Model (LAM), of the U-wind on the first model level, displayed with colour filled contours. The data is at T+3 from a 12Z run of the LAM from 24/10/95. The colour scale shown with the plot has been modified to reflect the colour filled contours.

4.2 Changes to the UM - to be implemented in Autumn 1997

The UM has gone through a number of revisions since its inception. The present operational version is **4.0**, running on the Met. Office Cray-916. The code has been written mostly in Fortran 77 and C. During late 1996, the Met. Office purchased a Cray T3E to replace the C-916. The T3E is a massively parallel machine, holding eventually 696 processors. The UM code will be compiled with the new Fortran 90 compiler. Future new versions of the UM will feature higher resolution global and mesoscale models, the former replacing the existing LAM.

- **Global version of the UM** Horizontal resolution will be $\simeq$ 60km; and 30 vertical levels.
- **UK Mesoscale version of the UM** A slightly larger domain to the existing UK mesoscale model and possibly an increased horizontal resolution. The actual coverage has yet to be decided.

Table 1 lists the different versions and release dates of the UM since 1993. A detailed list of the incremental changes is available from Peter Panagi.

Model Version	Release Date
4.3	June 1997
4.2	17/1/97
4.1	20/8/96
4.0	12/1/96
3.5	4/8/95
3.4	24/1/95
3.3	3/6/94
3.2	6/9/93
3.1	30/3/93

Table 1: Version changes and dates of release for the UM

The following lists major scientific changes between the different versions

- Version 3.4 : anisotropic gravity wave drag, orography in boundary layer, cloud microphysics in short-wave radiation, trace gasses in long-wave radiation, multi-layer soil hydrology, large-scale precipitation, convection, local reset of negative humidity, dynamic sea-ice in SLAB model, ice cavitation in OCEAN model, 3DVAR assimilation interface, new coastal adjustment in reconfiguration.
- Version 3.5 : X-windows interface for job setup, control changes for parallel running
- Version 4.0 : 3CV physics - improved mixed phase, correct QSAT, cloud microphysics effective cloud droplet radius, large-scale precipitation, improved evaporation of precipitation (large-scale+convective); Slingo-Edwards radiation scheme, Penman-Monteith hydrology, latent heat nudging in assimilation, long physics timestep, switch off horizontal diffusion for sloping levels, extra ocean options
- Version 4.1 : MOSES hydrology, Sulphur cycle within model, corrections to convection, diffustion, Slingo-Edwards radiation code, boundary-layer schemes rationalisation. This version is not used operationally.
- Version 4.2 : Intermediate build for Version 4.3. Includes massively parallel processor code options for the T3E. This version is not used operationally.
- Version 4.3 : Scientifically equivalent to Version 4.0; it will be used operationally on the T3E.

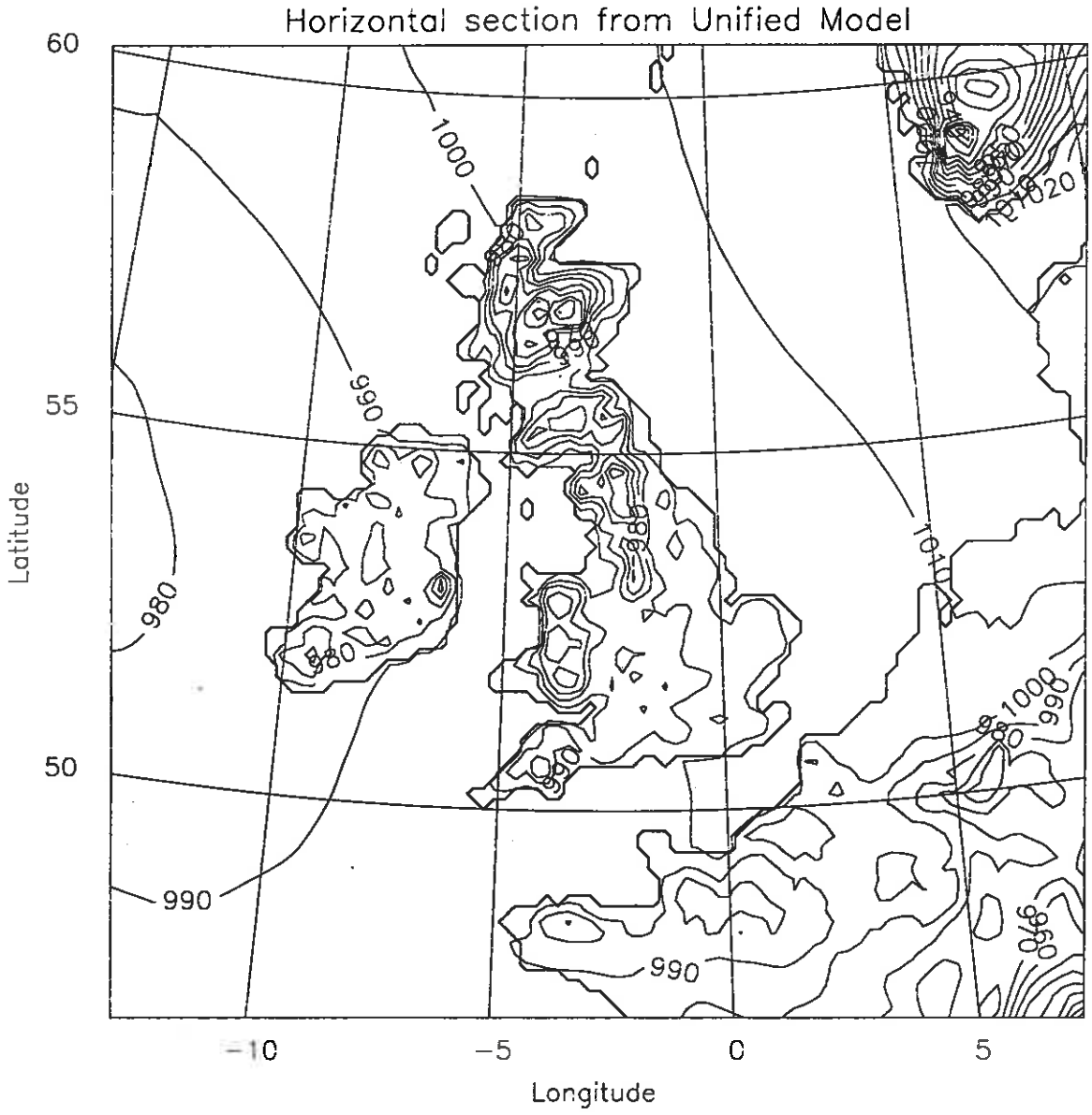

Figure 4: The region covered by the current UK Mesoscale model, with an example forecast at 03Z of mean sea-level pressure taken from a run at 0Z on 19/10/94.

5 TYPES OF DATA

In the following subsections, we list the types of data that are readily available, either stored at the JCMM or on the Met. Office's IBM mainframe. All these data can be readily extracted and made available to the user by the authors, but we should also point out that there are also many other kinds of data held at the Met. Office to which we can, in principle, get access but have no experience of obtaining. Should you be interested in any other data product, please contact Peter Panagi.

5.1 Unified Model data

5.1.1 The Unified Model data archives at Bracknell

The Unified Model archives contain data output from the operational Unified Model. This is the minimum requirement of forecasters at the the National Meteorological Centre (previously the Central Forecasting Office). The output is stored in one of two forms:

1. **On model η levels** - at present, 19 levels for both the GLOBAL and LAM runs and 31 for the UK MESOSCALE. The pressure at a given model η level is a linear function of the mean sea-level pressure (described elsewhere in this document). The number of diagnostics available is quite limited, and will usually be from the set given in Table 2

Model	Analyses	Frequency	Maximum Forecast period	Available fields
GLOBAL	00Z, 12Z	hourly	144	T, u, v, $\partial\eta/\partial t$, MSLP, p_*, specific humdity, cloud liquid water, cloud ice
LAM	00Z, 06Z 12Z, 18Z	3-hourly	36	T, u, v, w, $\partial\eta/\partial t$, MSLP, p_*, $\partial p_*/\partial t$, specific humdity, cloud liquid water, cloud ice
UK MESOSCALE	00Z, 12Z	hourly	24	T, u, v, w, $\partial\eta/\partial t$, MSLP, p_*, topography, specific humdity, cloud liquid water, cloud ice, convective cloud condensate
UK MESOSCALE	06Z, 18Z	hourly	36	T, u, v, w, $\partial\eta/\partial t$, MSLP, p_*, topography, specific humdity, cloud liquid water, cloud ice, convective cloud condensate

Table 2: Table of fields available on model η levels from the Met. Office archives. Headings are resolution, analyses times, end forecast time and field

2. **On standard pressure levels** - these are 1000, 950, 925, 900, 850, 700, 600, 500, 400, 300,250, 200, 150, 100, 70, 50, 30, and 10 **mb**. A list of the large number of available fields is given in Appendix A

The data are held on an IBM mainframe and require us to do some manipulation to convert the data to IEEE for UNIX machines. **32-bit IEEE** is the format that we support, and data come to you in this format, although we can provide the data in ASCII if it is necessary to convert to your own machine's internal binary format - this will be necessary, for example on a DEC machine, because the bytes that make up real and integer numbers are read in the reverse order.

UM global and LAM data are available from mid-1993, and will be held for approximately 5 years in the archives (in remote store) and 18 months on a rolling archive. The UK mesoscale archives begin from July 1995 and are kept for 5 years and also on an 18 month rolling archive.

5.1.2 The UM re-run archives

In addition to the UM data archives, the files required to re-run the UM are also archived. This may be necessary if the requested data are not available in the archives or cannot be computed using any of the diagnostics tools described in Section 9.1. All data are stored on the Met. Office's IBM mainframe, in Cray format, and fron July 1997, in 64-bit IEEE. The files needed to re-run the model are the boundary data, observations data and analyses. The boundary data for the UK meososcale model have been generated from a previous run of the LAM, while those for the LAM itself come from a previous global model run. Data are assimilated into the UM every six hours for global runs and three hours for the LAM and mesoscale models and the various observations files are also archived on the IBM mainframe. In addition, analyses are required to re-run the model. These files contain data from a previous run of the model at the same resolution so that the model can be re-started at any time.

The re-run archives are on a rolling basis, and only the last 18 months' data are kept. Therefore, it is only possible to re-run the model for cases within the last 18 months. It is possible however to re-generate the observation files needed for an older re-run from another general observational database, also held on the mainframe, but at the time of writing this document the authors have no experience in this area. In fact, few people in the Met. Office itself have this experience.

5.2 Observational data

In this section, we describe some of the different types of data that are available, either from the JCMM, which are simple to de-rachive and quick to obtain, or the Met. Office which take longer to obtain. Satellite, radar and sferics lightning data are all held at the JCMM, while upper air data are held by the Met. Office and the BADC (UK only), and surface and other data are all held at the Met. Office. Table 3 summarises all the archived data types, their respective file sizes, frequency and date of first availability.

5.2.1 Network radar data

UK radar precipitation data are available dating back to June 1992. The data are normally available at **15-minute** intervals throughout any 24-hour period. The maps are composites of basic data from some 15 individual radar sites, being at an approximate resolution of 5km. The data are also available processed, that is, data that have been passed through the Met. Office's FRONTIERS processing system (superceded by another system NIMROD) - details of the FRONTIERS and NIMROD processing systems can be obtained from Peter Panagi.

The basic data are held at the JCMM, and are stored as VMS DAT archives (historical reasons), but are readily accessible and can be used by the Unix-based graphics utility JPLOT which runs under IDL (see Section 10.1). Fig. 5 shows a typical radar image.

The data can also be overlayed on Unified Model output (and soon satellite data) for easy and direct comparison.

The file format is HEADER+DATA, where the HEADER is a mixture of INTEGER/REAL and the DATA are BYTE values.

5.2.2 Satellite data

Three types of satellite imagery are readily available from the JCMM archives. These are

- Meteosat infra-red images
- Meteosat water vapour images
- Meteosat visible images

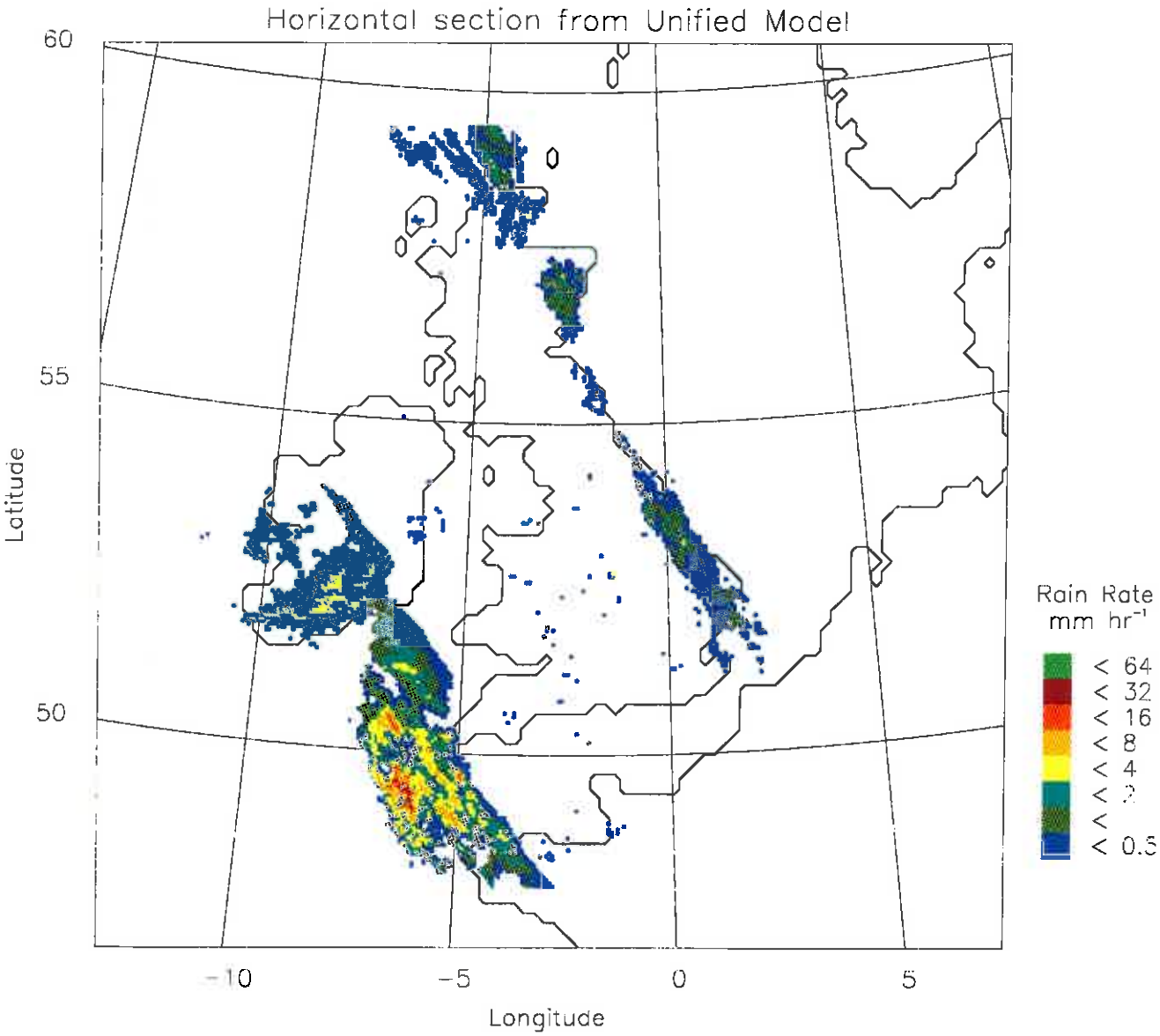

Figure 5: Radar image at 04:30 on 6/1/96, generated by JPLOT

Type	File size	Frequency	Available since
Satellite Infra-Red	1Mb	3-hourly	June 1992
Satellite Water vapour	1Mb	3-hourly	June 1992
Satellite Visible	1Mb	3-hourly	June 1992
Satellite Infra-Red	1Mb	1/2-hourly	January 1997
Satellite Water vapour	1Mb	1-hourly	January 1997
Satellite Visible	1Mb	1/2-hourly	January 1997
Radar	26Kb	15 minutes	June 1992
Sferics	Variable	5 minutes	June 1992

Table 3: Observation data held at the JCMM, showing type, typical file size, frequency and first available date. Sferics file sizes depend on the number of events.

The images cover the north Atlantic, eastern US and western Europe and have been projected onto a uniform x-y polar-stereographic grid. A typical I-R image is shown in Fig. 6. The approximate corners of the images are (68N,102W), (32N, 54W), (16N, 10E), (33N, 47E) and are not uniform in latitude and longitude.

As with the radar images, satellite data can be overlayed onto Unified Model fields within the IDL program JPLOT (see 10.1).

The file format is HEADER+DATA, where the HEADER is a mixture of INTEGER/REAL and the DATA are BYTE values.

NB Important - IDL version 4.0 does not draw the coastlines exactly where they should be over the satellite data (on a polar-stereographic projection), using the MAP routines. There appears to be an irregular pixels shift across the plot. The problem has been reported to Floating Point Systems.

5.2.3 Sferics lightning data

Sferics data tabulate lightning strikes around the globe. The position of lightning strikes are computed by taking data from a number of stations and correlating the time-lags between observations from the different stations. The Met. Office standard sferics dataset uses 7 stations from the UK to Cyprus. The files are ASCII and contain the latitudes, longitudes and times of events. The data are stored in 3-hourly files. Figure 7 shows events near and over the UK for the 24-hour period of 11th May 1997, a particularly active day.

Table 3 summarises all the archived data types, their respective file sizes, frequency and date of first availability.

5.2.4 Upper Air and Surface data

Radio-Sonde ascents are available for the 13 or so upper-air stations in the UK and Ireland since about 1990. Surface data for about 14 UK stations are also available dating back to 1990. Both kinds of data are available through the BADC at RAL. More information and data can obtained by contacting the BADC via any of the following

email badc@rl.ac.uk
www http://www.badc.rl.ac.uk
tel 01235 446432

The file format is ASCII so can be read and printed easily on any machine.

Figure 6: Meteosat infra-red image covering the north Atlantic and westen Europe

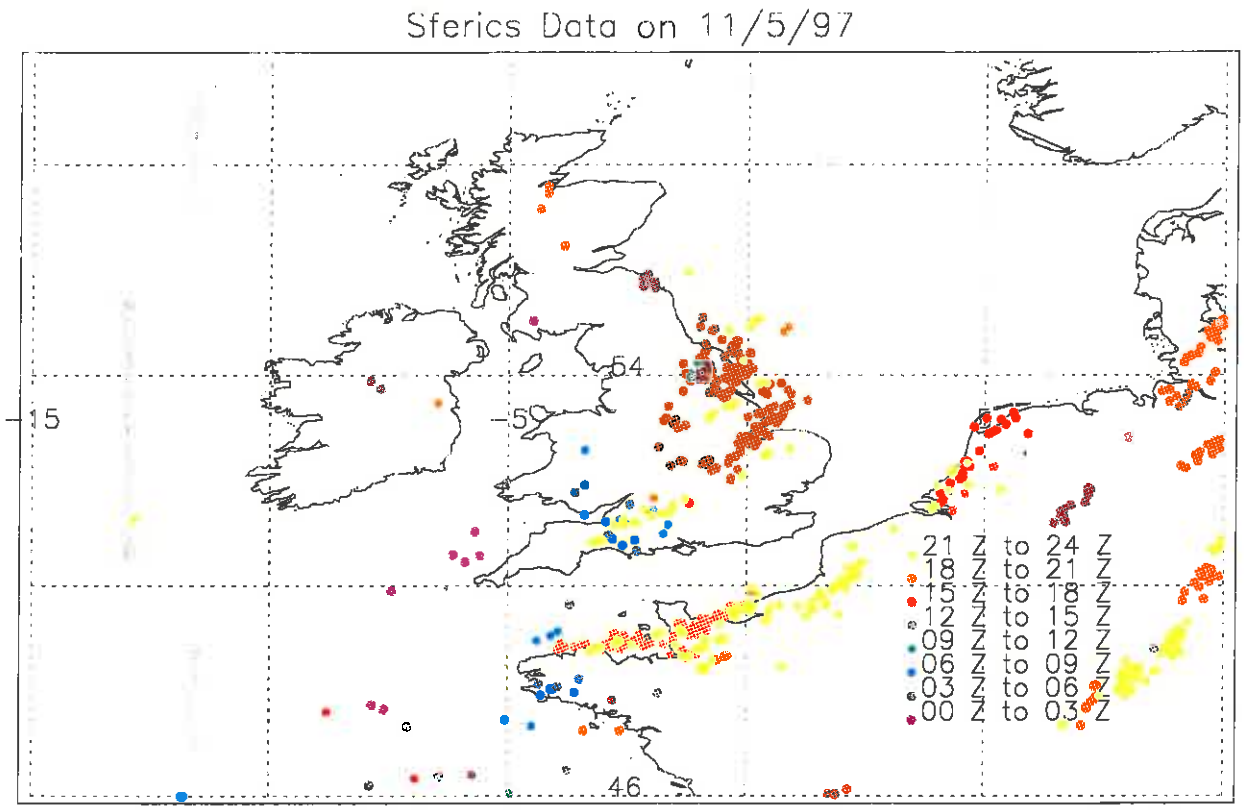

Figure 7: Sferics data from 11/5/97 plotted on an IDL Map Projection using JPLOT. The data plotted consists of 8 Sferics files each consisting of 3 hours worth of data so that each coloured dot represents activity some time in a 3 hour interval. It is also possible to superimpose UM data fields on the Sferics plots, and also to plot an arbitrary amount of Sferics data.

6 GETTING THE DATA TO YOU

We spell out here the way in which we obtain the data from the archives and get it to you. In general, we perform the following two-stage process :-

1. restore the data to a scratch disk and transfer it to a dedicated machine
2. ftp the data to the user

As has been mentioned earlier, the majority of data are held either at the JCMM (most satellite data) or on the Met. Office's IBM mainframe (UM archives). The length of time in restoring data for the user is, at present, independent of where it is stored. This may change during 1997 as the Met. Office will change its mass storage system to an as yet unknown system. We hope the transition will cause minimal disruption.

- UM archived data - the data are on the IBM in IBM format and need to be converted to IEEE. The procedure is a multi-stage process, requiring data to be restored to disk, broken up into REAL/INTEGER, transferred across to a UNIX workstation, converted to IEEE and then finally sent by **ftp** to an account specified by the user.
  TIMESCALES: Data from up to 8 UM runs can be obtained within 48 hours. Larger datasets take proportionately longer, as only 8 day's worth can be held on line at any one time.

- UM re-run archives - the data are held on the IBM in Cray format. From July 1997, when the T3E version becomes operational, the archives will be in 64-bit IEEE. Conversion utilities will be available for conversion between the 64-bit IEEE and Cray format, for use on Cray vector machines.

- Satellite and radar data are held at the JCMM as VMS backups. The data are straightforward to restore, and the data are then transferred to the dedicated workstation for transfer to the user via ftp.
  TIMESCALES: Reasonable volumes of data ($\sim$ 100Mb) can be on the user's machine within 48 hours.

- Surface and upper air data are held on the IBM at the Met. Office in a large database. The data are usually obtained for the user by the BADC, but in **exceptional circumstances** we can obtain the data for you, in which case the data are extracted from the database, transferred across to the dedicated workstation in ASCII format, then transferred to the user via ftp.

The above timescales depend on the number of existing data requests and other work that we are doing. Priority will be given to UWERN members.

7 YOUR COMPUTING REQUIREMENTS

7.1 IDL Graphics

The IDL graphics programs that will be described later in this document are intended to run on a Unix workstation. If you do not at present have any IDL licenses then they may be purchased from:

Floating Point Systems UK Ltd.,
Ash Court,
23 Rose Street,
Wokingham,
Berkshire,
RG40 1XS.

Tel: 0118 9776333
Fax: 0118 9776433

There are 2 types of licence available, a licence attached to a particular machine, or a floating network licence so that IDL may be used by designated machines on your network. We have experience of using IDL on Sun and SGI platforms and would advise the minimum specification machines suitable for using IDL would be a Sun 5 and a SGI Indy workstation. It is also assumed that you have a reasonable amount of disk space for storing data etc.

The current cost of a single-user license is about £1600 +VAT and for a 6-user license about £3250 + VAT.

7.2 Installing and running the UM

We have experience of running the UM on a Cray J-932 (32 processors, 8 GByte memory) but the UM should run successfully on any Cray computer. We have also run the UM on an SGI Power Challenge (4 processors, 1 Gbyte memory). These are the types of machine that should be considered when running the UM, although it can be run on a dedicated HP 9000 workstation.

- **DISK SPACE: 2Gb** It is to be noted that a storage capacity of around 2 Gbytes is required to install and run the UM system effectively.

As an example, a run of the UK Mesoscale model requires at least 45 MBytes of start data with the possibility of outputting a total diagnostic volume of 500 MBytes, but this figure is very much dependent on your diagnostic requirements. Therefore it can be seen that if you want to run the UM then you need a lot of disk space.

- **DISK SPACE: up to 500Mb** Typical output from a UK Mesoscale run.
- **CPU: 100 minutes Cray J-932** of run time for an 18-hour UK Mesoscale forecast run (N.B. only 1 CPU used).
- **CPU: 500 minutes HP 9000/755** for a LAM run, to T+48

7.3 Diagnostics programs

Using the post-processing package **MDIAG** (section 9.1), it is possible to generate a number of diagnostics from some basic UM data. Using data from a typical LAM forecast run from the Unified Model, out to T+36 3-hourly (i.e. 13 time steps), and saving all 49 of the currently available diagnostics, requires the following computing resources.

- **DISK SPACE: up to 1Gb** , made up of 150 Mb for the original LAM data + 850 Mb for a full 49 diagnostic output. This **can be significantly reduced** by judicious use of forecast times and output diagnostics, since the it is not expected that the user will require all 49 diagnostics - see equation 1 for a more detailed description on how to compute file sizes.
- **COMPUTER MEMORY: 100Mb** of allocatable stack/data space in memory is required for the FORTRAN code to run - this depends again on the number of diagnostics required. The program allocates memory as it is needed because it has been written as a series if subroutines whose parameters are called at run time.
- **CPU TIME: 3000s** on an HP/9000/735/99. This is for code that has been maximally optimised by the compiler.

8 RE-RUNNING THE UM YOURSELF

8.1 Why Run the UM?

The main reason for wanting to re-run the UM yourself is to provide case study diagnostics that are not available from the Met. Office Forecast data archives or cannot be obtained from the UM-data diagnostic program MDIAG (see Section 9.1). If the data are available from these two sources, it may be appropriate to request the data from Peter Panagi at Reading who will obtain the data and transfer it to you via ftp or DAT tape.

At present we have experience of running the UM on Cray and SGI computer systems. It should be straightforward to run the UM also on HP and Dec Alpha systems as these are designated for support by the Met. Office. Reading JCMM members run the UM on the Cray J-932 at the Rutherford Appleton Laboratory (RAL) at Chilton in Oxfordshire, with the UM being permanently set up on this machine. If you do not have an account on this machine (and are not able to gain one) then the UM will have to be built on your own Unix system; this will be done by Ed Dicks at Reading. However, if you plan to do many UM runs then we encourage you to apply for Cray time at RAL, who also have a data archiving system which is very useful as the UM can generate very large quantities of data.

8.2 The Unified Model User Interface

UM runs are set up using an X-windows tool provided by the Met. Office called the Unified Model User Interface (UMUI). This is a hierarchical series of windows containing the various options for setting parameters specifying a model run. The UMUI is also used for specifying exactly what diagnostics are required from a model run; this is done in the STASH (Spatial and Temporal Averaging and Storage Handling) section of the UMUI. In general, the UM is designed to produce diagnostics during a model run rather than significant post-processing facilities being used to obtain diagnostics, however the MDIAG program is now available as a post-processor to calculate certain diagnostics; see section 9.1 on the MDIAG program for more details. The model run can then be submitted to the required computer from the UMUI using the rsh (remote shell) facility. The Met. Office provide a number of standard UM job setups (called basis files) which may be loaded into the UMUI and modified according to your specific requirements; also jobs may be exported from the UMUI so that job setups may be transferred from group to group.

The UMUI is written in the tcl/tk tools and C code and will need building on your local system, again this will be done by Ed Dicks at Reading. The UMUI has a capability for the remote submission of a model run and therefore does not need to be installed on the same machine as the UM is run. For more details on the UMUI see the UKMO document entitled "Unified Model User Guide", accompanying this document. New users of the UMUI will receive initial guidance on its use from either Ed Dicks or Peter Panagi at Reading.

8.3 Data Required for Running the UM

The data needed to run the UM, comprising analyses, boundary data, observational data and ancillary files, depends on the type of model being used, i.e. UK Mesoscale, LAM, global, etc. The different types of UM data are outlined below:

- Analyses - Contains the initial data needed for a run, i.e. prognostic variables and surface and sea quantities, e.g. soil and sea parameters.
- Boundary data - used for updating the model boundary values during a model run. For the UK Mesoscale model, they are generated from runs of the LAM model.
- Observational data - Files contain various observational data which are used when data assimilation is required.

- Ancillary data - Files containing a particular surface/sea parameter such as the height of the land surface or climatological quantities such as sea surface temperatures.

In this document we concentrate on the UK Mesoscale area which requires an analysis, boundary data, possibly ancillary data files, and again possibly observational data if running in data assimilation mode. A global run would require an analysis and possibly ancillary files, but not boundary data.

8.4 Output from Running the UM

The diagnostics available for output from the UM are extensive. There is also the possibility of specifying various additional output processing options such as accumulating fields, calculating meaning sequences, defining sub-regions for output etc. Diagnostic output defined in the STASH section (see Appendix B) of the UMUI is directed to files termed "PP files". Many such files may be output from a model run, so that users can split up their output into different files to suit their application. A nearly exhaustive list of available fields and stash codes is given in Appendix C.

When the UM is run on a Cray computer the PP files will have "Cray format" numbers and so cannot be transferred to any other system, it is also possible to request "packed" PP files (by taking an option in the UMUI) to reduce their size, but any unpacking must take place on the Cray. When the UM is run on an IEEE type workstation the only possible type of PP file packing is Grib type, but we have no experience of this format of PP file. (**NB** - we note that the utlility ffpp2f (see below) is available to convert Cray format data to 32-bit IEEE, so that data can be used on workstations).

Unified Model Output and data files usually are structured in one of two ways: firstly 'FIELDSFILE format' or secondly 'PP-format'. All data needed for running the UM, i.e. analyses, model dumps, boundary data files and ancillary data files will be of FIELDSFILE format; 'PP files' obtained as output from running the UM are also of this format. However, when UM output data are supplied via the Met. Office data archives, this will usually be in PP-format.

The conversion of a Cray Fieldsfile type file to PP-format is desirable since PP-format files are readily portable to other Unix systems (since they are 32-bit IEEE f77 unformatted type) and are the most commonly used in graphic/diagnostic processing. The conversion process using software in the UM distribution is normally a 2-stage process and involves transferring the data file from the Cray to a workstation to perform one of the stages. However, a utility called ff2ppf has been written to perform the conversion as a 1-step procedure on the RAL Cray. The Cray shell script ff2ppf resides in /home/j90/emd/umod on the Cray J-932 at RAL, the input and output file names may be specified within the script. If you have a Cray account at RAL you can copy the script which will access my copy of the required executable. The utility ff2ppf has the advantage over the UKMO utilities in that it may convert an incomplete Fieldsfile file to PP-format. N.B. If the Fieldsfile file was generated from a model run on a Unix workstation then the file can be converted to PP-format in 1 step using the UM system utility convpp.

PP-format files contain headers and data records interleaved; the structure of the header record can be found in Appendix B. The PP-format file can be used for visualisation or can be manipulated with a fortran program; an example piece of f77 code is available for reading these files, called readppf.f and is available from Ed Dicks at Reading. To compile this piece of code on the Cray use the command:

```
cf77 -o readppf readppf.f
```

and on a workstation use:

```
f77 -o readppf readppf.f
```

9 MANIPULATION OF UM DATA

9.1 MDIAG - a diagnostics suite of programs

MDIAG is a suite of FORTRAN programs used to compute a variety of diagnostics using UM data on regular pressure levels (100mb for the LAM and 50mb for the UK MESOSCALE model).

The aim of MDIAG is to compute as efficiently as possible a large number of diagnostics using the **six basic fields, geopotential height (g), temperature (T), westerly (u) and northerly (v) winds, specific humidity (q) and vertical velocity (w)** output from the UM. Thus it is possible to generate useful research tools for individual case studies and also for a statistical analysis of a number of weather events, without having to re-run the UM.

A full description of the program, how to compile and execute it, and a full list of the diagnostics and the associated subroutines is given in Appendix E.

NB There are two version of MDIAG available. One uses COMMON blocks and the other solely by self-contained calls to individual subroutines where all the necessary parameters are passed through the argument list. The COMMON block version runs some 5 times quicker than the latter version, but the executable is enormous (50Mb for the UK Meososcale model and 90Mb for the LAM). **Both** versions require you to have a Fortran compiler that allows the dynamic allocation of arrays, however a standard compiler version will be available very soon.

Below we give the a summary of the diagnostics for quick reference.

Horizontal derivatives
Grad (∇_h), Divergence ($\nabla_h .$), Curl ($\nabla_h \times$)
$\partial/\partial\lambda, \partial/\partial\phi, \partial/\partial p, \nabla^2$
advection ($v.\nabla$), geostrophic advection ($v_g.\nabla$)

Vertical derivatives
$\frac{\partial u}{\partial p}, \frac{\partial v}{\partial p}, \frac{\partial \theta}{\partial p}, \frac{\partial \theta_e}{\partial p}$

Thermodynamic variables
pressure at mean sea level
specific humidity q
potential temperature θ
wet-bulb potential temperature θ_w
equivalent potential temperature θ_e
saturation equivalent pot. temperature θ_e^{SAT}
humidity mixing ration r
relative humidity wrt water and ice RH
saturation vapour pressure e_s
virtual temperature θ_V
density ρ

Other meteorological variables
Potential vorticity PV (both dry and moist)
geostrophic wind v_g
Divergence (velocity)
Absolute vorticity, relative vorticity
Geostrophic Relative Vorticity
Q-vectors

Frontal analysis
Magnitude Geostrophic Deformation
EW and NS components of the geostrophic deformation axis

Geostrophic Deformation wrt θ_w
Magnitude $\nabla\theta, \nabla\theta_w$
EW and NS components of $\nabla\theta, \nabla\theta_w$
$\nabla^2\theta_w, \nabla^2\theta$
Frontal Speeds - advection of $|\nabla\theta_w|, |\nabla\theta|$
advection of θ, θ_w
Geostrophic advection of θ, θ_w
Local value of $|\nabla\theta|, |\nabla\theta_w|$
N-S and E-W components of Q-vectors tangent and normal to constant θ, θ_w surfaces

The following will be added shortly
Ω-equation diagnostics
Ω-equation inversion with $\nabla.Q$ & diabatic forcing
Ω-equation inversion with diabatic forcing only
Ω-equation inversion with $\nabla.Q$ only
Ω-equation inversion with $\nabla.Q$, between 800-600mb
Ω-equation inversion with $\nabla.Q$, between 600-100mb
Ω-equation inversion with $\nabla.Q$, between 1000-800mb

9.2 EXFIELD

Unified Model datasets are often too large to be loaded into, for example, the IDL graphics program JPLOT. For this reason a utility called exfield has been written which extracts a user-defined subset of data from the UM data file. This subset of data can then be loaded into the graphics application. As a rough guide, if the UM data file is of the order of 100Mb in size then exfield will probably be needed to produce smaller subsets of data. However, it really depends on the disk space and memory configuration of your system as to whether you need to use exfield.

The exfield script can extract data from both FIELDSFILE type and PP-format type files, by calling a different executable for each. If you have a RAL Cray account then you will be able to access the executables, whereas if you are working on a workstation then we will supply the source code but in this case exfield is only designed to work with PP-format files, so any Fieldsfile type files will need converting to PP format.

The extracted data may be written out either as a PP-format file or in a simple (IEEE 32-bit F77 Unformatted) manner, preceded by a simple header containing resolution and domain details, etc. These data file formats have been programmed into the JCMM IDL data visualisation program JPLOT so that an option exists for loading either of these UM Data files. Although JPLOT may only load PP-format files under certain restrictions. It is recommended that exfield is used to extract data and write it in PP-format as this is the most common UM file type.

10 GRAPHICS PROGRAMS

At present, we support one graphics program for the display of UM and related data. The main program that we expect people to use will be JPLOT, an X-windows based point-and-click program that runs under IDL, as most university and research institutions have IDL. The program was written by Ed Dicks at the JCMM. The present version of JPLOT works with IDL 4.0; however, we await the imminent release of IDL 5.0. We will make JPLOT work under the latest versions. There are, however, two further graphics programs available DISP and PV-Wave; both are used by the Met. Office and the Meteorology dept. at Reading University and are briefly discussed below. Should users require either of these packages, we will point them in the right direction and provide a minimal level of support.

10.1 IDL and JPLOT

JPLOT is an X-based interactive plotting program for displaying Unified Model data and related observational (satellite and radar) data. An introductory guide is given in Appendix D

JPLOT is a fully interactive X-Windows widget based IDL graphical display program, designed to run on IEEE Unix systems. At present it is capable of reading 8 different dataset formats, however in this document we only consider use of JPLOT with Unified Model (UM) data as this is the most applicable to the UWERN collaboration. For details about the other datasets usable with JPLOT please contact Ed Dicks at Reading.

JPLOT can read in two types of file containing UM data, the program interrogates the input file to deduce which type of file is supplied. The two file types are:

1. PP-format files; this is the most common type of UM data file. However there is a restriction when reading these files directly, this being that there must be no more than 120 multi-level fields in the file. If this restriction does not hold then the second type of file must be used. There is no restriction on the number of single level fields present in the PP-format input file. **NB** Smaller PP-format files may be generated using the utility EXFIELD (see Appendix F).

2. UM data extraction; this file contains a user specified subset of a PP-format file or Fieldsfile type file, and is created by running a pre-processing job (with script exfield, described in Appendix B) on the PP-format or Fieldsfile file. This option is useful when the UM datasets are very large.

The data can be displayed in JPLOT a number of ways:

- Any arbitrary 2D orthogonal section through a 3D field
- Oblique vertical sections, from one grid point to another
- Any arbitrary orthogonal column or row of points producing an x-y line plot.
- Velocity vector plots (which may be overplotted) assuming U and V winds are present.
- 3D Iso-surface plots.

The user can then display the 2D sections in a number of ways, for example using images, contours or surface plots. Also various tool are available such as zoom utilities and other data field manipulation widgets. UM data may be displayed either on a rectangle corresponding to the equatorial grid (which the limited area models are run on) or with a standard cylindrical map projection. An overplotting facility also exists for plotting one field over another. The user can interactively alter various display parameters such as contouring parameters (values, linestyles, labeling, etc.) and axis values and titles etc. Hardcopy of graphical output can be obtained with a Postscript creation facility, which will be described later on. Figures 8,9,10 show example output from JPLOT; the pressure at mean sea level over the LAM area, a vertical cross-section through the x-z plane running through the middle of the UK mesoscale region and a UM temperature field overplotted on a satellite I-R image.

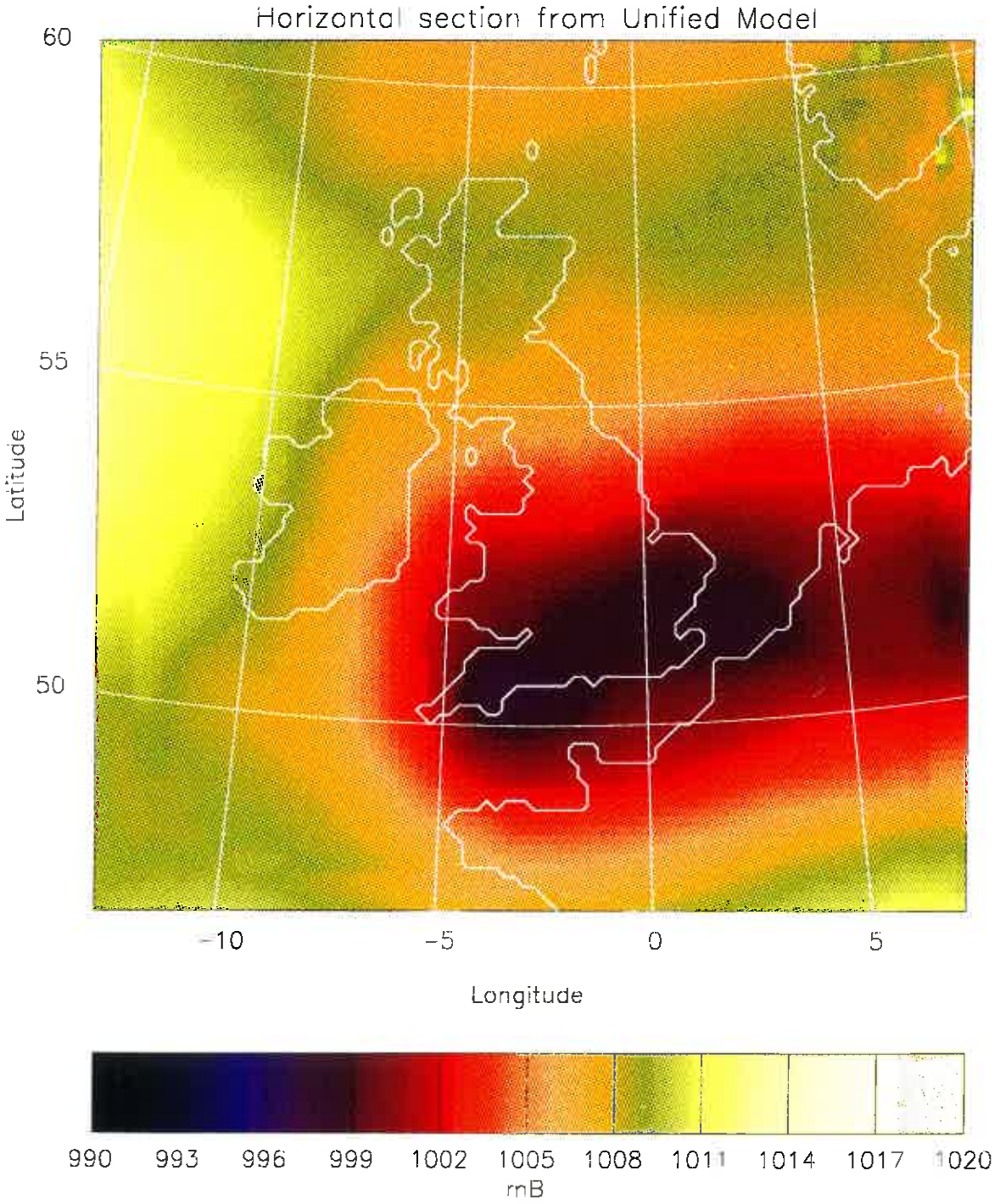

Figure 8: An image plot of PMSL forecast at T+6 from 00Z on 17/5/95

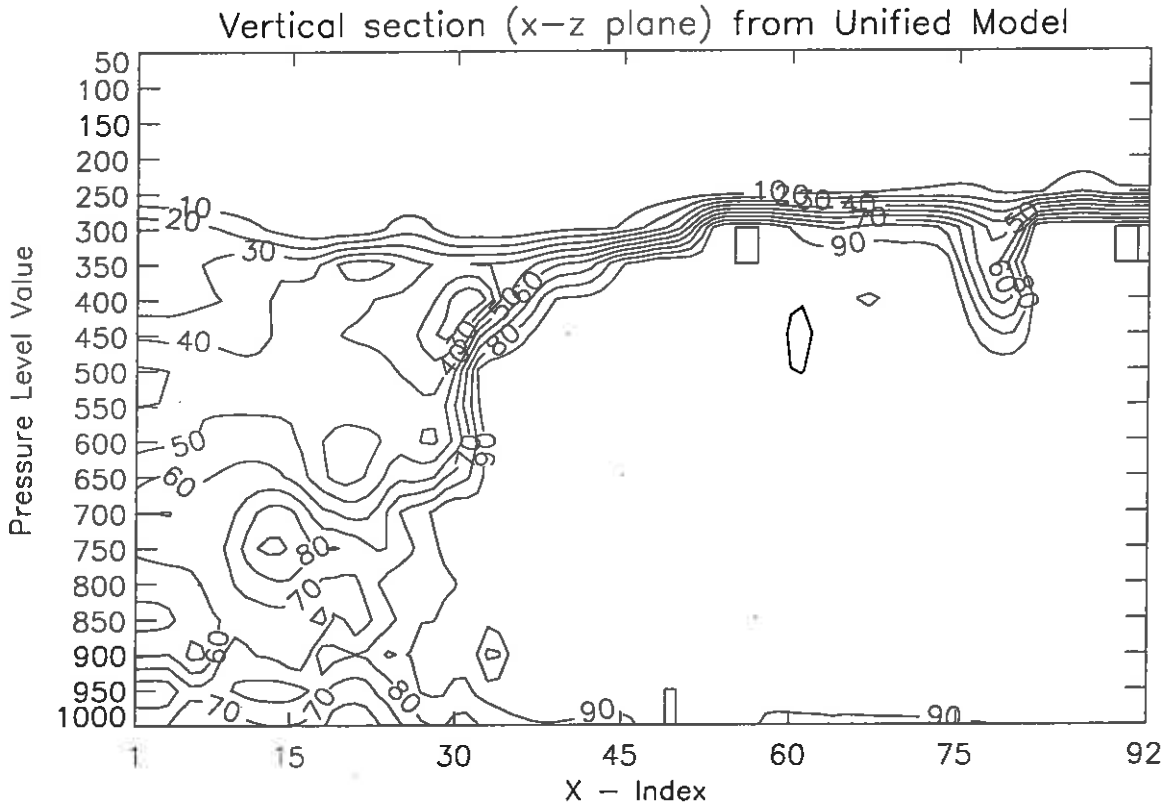

Figure 9: A contoured vertical section in the X-Z plane running approximately through the middle of the UK Mesoscale region. The field displayed is Relative Humidity with a contour level increment of 10%. The data is at T+12 from a run of the UK mesoscale model from 0Z on 17/5/95.

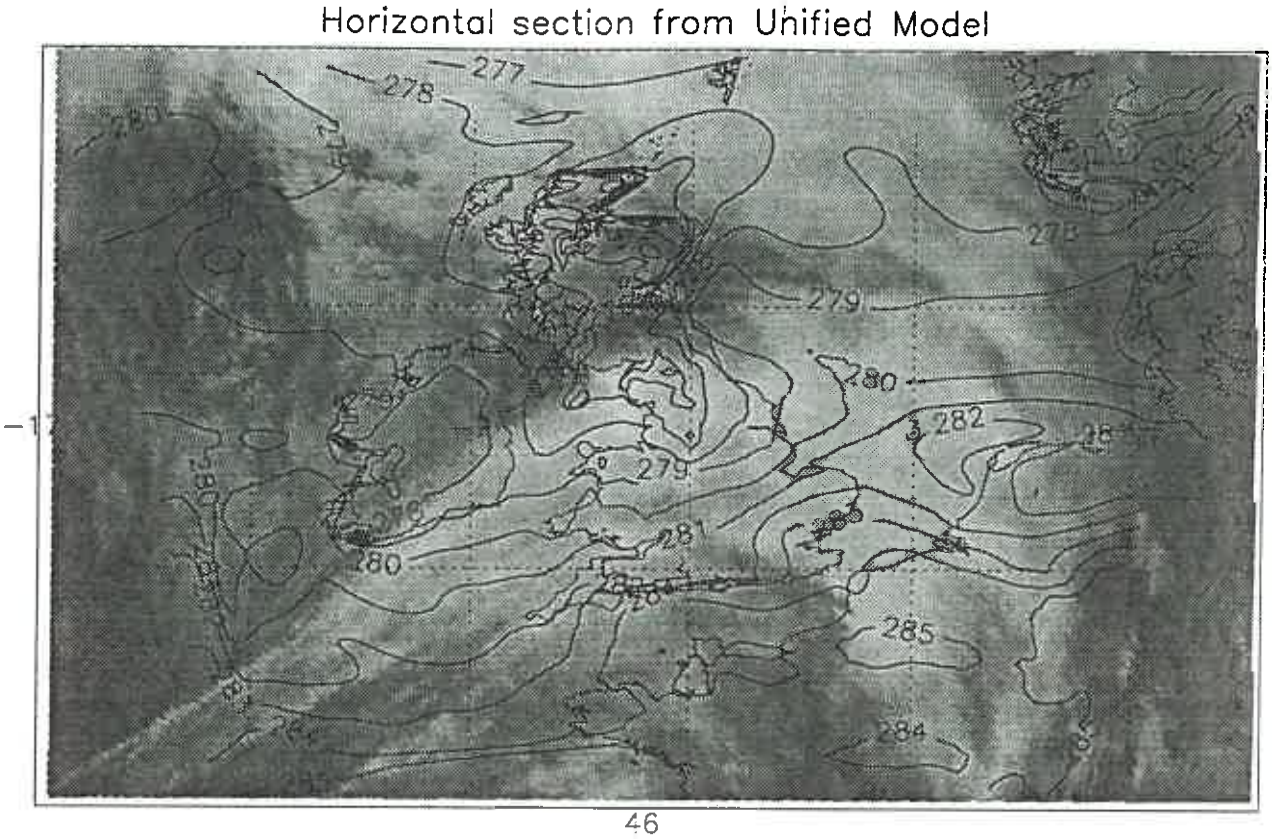

Figure 10: Satellite I-R data and UM temperature field overplotted

A useful feature of JPLOT is that it has an option to call IDL procedures supplied by the user, so that JPLOT variables and displays may be manipulated in a more user specific way. The user may supply the names of these procedures during execution of JPLOT; this is described in more detail in Appendix D. Other sections of the JPLOT document describe some supplied user procedures and some stand alone procedures that may be used with UM data. The method of producing UM data animation sequences is described in Appendix D.10.

10.2 DISP

DISP is a PC-based graphics program, written in Turbo Pascal primarily by Tim Hewson (JCMM). DISP can read plot and overplot UM, satellite, radar and sferics data. UM data must however be on a polar-stereographic grid and two dimensional, i.e. on a constant surface. The only UM data that DISP can handle is on a 61x38 grid at 100km resolution, a special low-resolution subgrid of the original LAM grid. Polar-stereographic data must have been generated using a special version of the diagnostics package MDIAG, which works on a three-dimensional dataset, and then passed through subsequent programs to extract data onto constant surfaces, either pressure, PV or θ surfaces. These programs only work under VAX VMS, primarily because that is where they were first developed, but also because of the nature of the PC-type files that DISP requires.

At the JCMM, we archive the UM DISP-grid data on certain pressure levels. The archives date back to mid-1992. Please contact Peter Panagi for further details.

10.3 PPLOT and PV-Wave

PV-Wave is, to all intents and purposes, a commercial graphics program identical to IDL. A few years back, the two products were in fact one and the same, being marketed by the same US-based company RSI. In the last few years, PV-Wave has been marketed by a separate company, and has developed separately from IDL. The basic syntax and many of the utilities are still almost identical,

but the X-based widgets are somewhat different. The Met. Office has taken this product on board and developed a large number of graphics utilities for displaying UM data. At the JCMM, Humphrey Lean has develpoed a very simple-to-use point-and-click menu-driven system for displaying UM data, PPLOT. This is based on a number of underlying PV-Wave routines written by the Met. Office Hadlee Centre. If you have PV-Wave, contact Peter Panagi for a discussion of the how best to obtain and set up PPLOT and the underlying routines.

11 FURTHER DOCUMENTATION

The Met. Office has a large number of internal documents relating to the entire Unified Model project, from conception, through research to implementation. Tables 4, 5 give listings of the currently available scientific and technical papers. There are of course numerous other scientific and technical documents relating to the UM project which are not listed in the tables.

If you require any UM-related documentation, please contact Peter Panagi in the first instance.

Paper	Title	Authors
000	Unified Model User Guide	NWP, CR Divisions
002	Change control management of the UM system	F.Rawlins
003	Software standards for the UM: Fortran and Unix	P.Andrews
004	Maintenance of frozen versions of the UM	F.Rawlins
005	Notation, physical constants, units and names variable	C.A.Wilson
006	Cray autotasking system & performance utilities	R.S.Bell
007	Filenaming conventions for the UM system.	T.C.Johns
010	Conservative finite difference schemes for a Unified forecast/climate model.	M.J.P.Cullen,T.Davies, M.H.Mawson
011	Positive definite advection scheme.	M.J.P.Cullen
013	Derivation and calculation of PV	S.Anderson, I.Roulstone
014	Solution of Poisson's equation on the sphere using Fourier transforms	M.H.Mawson
021	Vertical Diffusion	C.A.Wilson
022	Gravity wave drag	C.A.Wilson, R.Swinbank
023	Radiation	W.J.Ingram, S.Woodward, J.Edwards
024	Subsurface, surface and boundary layer processes	R.N.B.Smith
025	Canopy, Surface and Soil Hydrology	D.Gregory, R.N.B.Smith, P.M.Cox
026	Large-scale precipitation	R.N.B.Smith, D.Gregory, J.F.B. Mitchell A.C.Bushell
027	Convection scheme	D.Gregory, P.Inness
028	Energy correction	D.Gregory
029	Calculation of SSH and large scale cloud	R.N.B.Smith, D.Gregory, C.A.Wilson
030	Analysis Correction Data Assimilation scheme	RS Bell, AC Lorenc, B Macpherson R Swinbank, P Andrews
032	Quality control of atmospheric data	N.B.Ingleby, C.Parrett
070	Specification of ancillary fields	C.Jones
071	Specification of sea-ice fields.	C.Jones
072	The SST analysis system	C.P.Jones, D.L.Harrison, E.B. Little
073	Ancillary file creation for the UM	D.Robinson
080	Dynamical and physical Diagnostic calculations.	P.J.Trevelyan

Table 4: A list of Unified Model Documentation (scientific) papers. UM papers are Crown Copyright.External users may print papers, but may not sell nor quote from them without permission.

Paper	Title	Authors
C1	Dynamic allocation of primary fields	F.Rawlins
C3	List of external files	M.Carter
C4	Storage handling & diagnostic system (STASH)	M.Carter, P.Trevelyan, T.C.Johns S.J.Swarbrick
C5	Control of means calculations	N.S.Grahame
C7	Updating ancillary and boundary fields in the atmosphere and ocean models	M.J.P.Cullen
D4	Diagnostics on pressure levels suitable for calculating eddy fluxes & variances of fields	R.Stratton
D6	Printed diagnostics	C.Douglas
D7	Test diagnostics for output	F.Rawlins.
F3	Dump (including ocean), fieldsfile, observation files and ancillary dataset format.	D.Robinson, A.Dickinson
F5	Unified Model file utilities	A.Dickinson
F51	Merge utility.	D.Goddard
F52	Modifying UM output fields	V. Blackman
P23	Radiation diagnostics available as standard	W.Ingram
P3	Technical details of the assimilation system	R.S.Bell.
P52	Quality control of atmospheric data	N.B.Ingleby, C.Parrett
S1	Interpolation techniques and grid transformations	A.Dickinson
S5	C Utility Routines	A.Dickinson
U3	Observations User Interface	G.Bason
X0	Unified Model for External Users	N. Farnon
X1	Portability considerations	A.Dickinson
X2	The update source code manager	R.Krishna
X3	Lexcon: dynamic memory compile preprocessor	A.Dickinson, P.Burton
X4	Guidelines for building the UM on external systems	T.Smith, N.Farnon
Z5	System maintenance procedures	G.Henderson

Table 5: A list of Unified Model Documentation papers. UM papers are Crown Copyright. External users may print papers, but may not sell nor quote from them without permission.

12 PROBLEMS, SUPPORT AND FEEDBACK

If you have specific software problems in any of the following areas, please contact the named person initially. We have divided our responsibilities into those areas with which we are most familiar so that you will get a quicker response to your problem.

- JPLOT Ed Dicks
- MDIAG Peter Panagi
- DATA Peter Panagi
- UM INSTALLATION ON CRAY AND WORKSTATIONS Ed Dicks
- RUNNING THE UM Ed Dicks
- UMUI Ed Dicks
- DOCUMENTATION Peter Panagi

Occasional updates of this report will be issued in response to changes in UM products and user feedback. Please check that you have an up-to-date version by looking at either of the WWW sites listed under Section 1

13 ACKNOWLDEGMENTS

We would like to thank Prof. Keith Browning for guidance as to the structure of this document and to Prof. Alan Thorpe for reading and correcting a preliminary version. We are also endebted to Drs. Alan Dickinson and Rick Rawlins of the Met. Office for their input and revisions and permission to use Met. Office internal documents.

Please note that all Met. Office documents are Crown Copyright, and prior permission to quote them must be obtained from the Met. Office. Please contact Peter Panagi in first instance.

A ARCHIVED STANDARD LEVEL DATA

Below are set out all the fields that are available on standard pressure levels from the three UM resolutions, giving field, unit, pressure level (mb) and forecast time

GLOBAL

Height m	Elapsed time of Forecasts (hours)																		
1000	0	6	12	18	24	30	36	42	48	54	60	66	72	84	96	108	120	132	144
950	0	6	12	18	24	30	36	42	48	54	60	66	72	84	96	108	120	132	144
925	0	6	12	18	24	30	36	42	48	54	60	66	72	84	96	108	120	132	144
850	0	6	12	18	24	30	36	42	48	54	60	66	72	84	96	108	120	132	144
700	0	6	12	18	24	30	36	42	48	54	60	66	72	84	96	108	120	132	144
600	0	6	12	18	24	30	36												
500	0	6	12	18	24	30	36	42	48	54	60	66	72	84	96	108	120	132	144
400	0	6	12	18	24	30	36	42	48	54	60	66	72	84	96	108	120	132	144
300	0	6	12	18	24	30	36	42	48	54	60	66	72	84	96	108	120	132	144
250	0	6	12	18	24	30	36	42	48	54	60	66	72	84	96	108	120	132	144
200	0	6	12	18	24	30	36	42	48	54	60	66	72	84	96	108	120	132	144
150	0	6	12	18	24	30	36	42	48	54	60	66	72	84	96	108	120	132	144
100	0	6	12	18	24	30	36	42	48	54	60	66	72	84	96	108	120	132	144
70	0	6	12	18	24	30	36	42	48	54	60	66	72	84	96	108	120	132	144
50	0	6	12	18	24	30	36	42	48	54	60	66	72	84	96	108	120	132	144
30	0	6	12	18	24	30	36	42	48	54	60	66	72	84	96	108	120	132	144
10	0	6	12	18	24	30	36	42	48	54	60	66	72		96		120		
Temperature K																			
1000	0	6	12	18	24	30	36	42	48	54	60	66	72	84	96	108	120	132	144
950	0	6	12	18	24	30	36	42	48	54	60	66	72	84	96	108	120	132	144
925	0	6	12	18	24	30	36	42	48	54	60	66	72	84	96	108	120	132	144
900	0				24														
850	0	6	12	18	24	30	36	42	48	54	60	66	72	84	96	108	120	132	144
700	0	6	12	18	24	30	36	42	48	54	60	66	72	84	96	108	120	132	144
600	0	6	12	18	24	30	36												
500	0	6	12	18	24	30	36	42	48	54	60	66	72	84	96	108	120	132	144
400	0	6	12	18	24	30	36	42	48	54	60	66	72	84	96	108	120	132	144
300	0	6	12	18	24	30	36	42	48	54	60	66	72	84	96	108	120	132	144
250	0	6	12	18	24	30	36	42	48	54	60	66	72	84	96	108	120	132	144
200	0	6	12	18	24	30	36	42	48	54	60	66	72	84	96	108	120	132	144
150	0	6	12	18	24	30	36	42	48	54	60	66	72	84	96	108	120	132	144
100	0	6	12	18	24	30	36	42	48	54	60	66	72	84	96	108	120	132	144
70	0	6	12	18	24	30	36	42	48	54	60	66	72	84	96	108	120	132	144
50	0	6	12	18	24	30	36	42	48	54	60	66	72	84	96	108	120	132	144
30	0	6	12	18	24	30	36	42	48	54	60	66	72	84	96	108	120	132	144
10	0	6	12	18	24	30	36	42	48	54	60	66	72		96		120		
Wind U-component m/s																			
1000	0	6	12	18	24	30	36	42	48	54	60	66	72	84	96	108	120	132	144
950	0	6	12	18	24	30	36	42	48	54	60	66	72	84	96	108	120	132	144
925	0	6	12	18	24	30	36	42	48	54	60	66	72	84	96	108	120	132	144
900	0				24														
850	0	6	12	18	24	30	36	42	48	54	60	66	72	84	96	108	120	132	144
700	0	6	12	18	24	30	36	42	48	54	60	66	72	84	96	108	120	132	144
600	0	6	12	18	24	30	36												
500	0	6	12	18	24	30	36	42	48	54	60	66	72	84	96	108	120	132	144

```
 400   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
 300   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
 250   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
 200   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
 150   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
 100   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
  70   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
  50   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
  30   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
  10   0   6  12  18  24  30  36  42  48  54  60  66  72      96      120
Wind V-component m/s
1000   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
 950   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
 925   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
 900   0              24
 850   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
 700   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
 600   0   6  12  18  24  30  36
 500   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
 400   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
 300   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
 250   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
 200   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
 150   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
 100   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
  70   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
  50   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
  30   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
  10   0   6  12  18  24  30  36  42  48  54  60  66  72      96      120
Relative humidity (dimensionless), or mixing ratio  kg/kg
9999   0   6
1000   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
 950   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
 925   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
 900   0              24
 850   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
 700   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
 600   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
 500   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
 400   0   6      18  24  30  36
 300   0   6          24
 250   0   6          24
 200   0   6          24
 150   0   6          24
 100   0   6          24
  70   0   6          24
  50   0   6          24
  30   0   6          24
  10   0   6          24
Vertical velocity Pa/s
1000   0   6
 950   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
```

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 925   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
 900           12  18  24  30  36
 850   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
 700   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
 600   0   6  12  18  24  30  36
 500   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
 400   0   6  12  18  24  30  36
 300   0   6  12  18, 24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
 250   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
 200   0   6
 150   0   6
 100   0   6
  70   0   6
  50   0   6
  30   0   6
Mean sea level (8888) or surface (9999) pressure    Pa
8888   0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48  51  54
      57  60  63  66  69  72  78  84  90  96 102 108 114 120 126 132 138 144
9999   0       6
Specific humidity at 1.5 m      dimensionless
9999   0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48  51  54
      57  60  63  66  69  72  78  84  90  96 102 108 114 120 126 132 138 144
Surface and B/lyr moisture flux (9999)      Kg/M**2/S
9999L 12  18  24  30  36
Surface temperature    K
9999   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
Wet-bulb potential temperature     K
 850   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
 500   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
CAT probability     dimensionless
8888  12  18  24  30  36  42  48
 300  12  18  24  30  36  42  48
 250  12  18  24  30  36  42  48
 200  12  18  24  30  36  42  48
Maximum CAT level  Pa
8888  12  18  24  30  36  42  48
Maximum CAT value Pa
8888  12  18  24  30  36  42  48
Snow probability    dimensionless
8888   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
-20DegC Isotherm True Ht     KFT
8888   0   6  12  18  24  30  36
Surface moisture flux over IREST t/s   kg/m**2 = mm/timeslic
9999   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
Wind mixing     W/m**2
9999   0   6  12  18  24  30  36  42  48  54  60  66  72  78  84  90  96 102 108
     114 120 126 132 138 144
Latent heat flux     W/m**2
9999   0   6  12  18  24  30  36  42  48  54  60  66  72  78  84  90  96 102 108
     114 120 126 132 138 144
Sensible heat flux    W/m**2
9999L  0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
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Net solar radiation flux top (8888) or bottom (9999) W/m**2
9999   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
Net IR at top (8888) or bottom (9999)      W/m**2
9999   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
Surface wind stress - U     N/m**2
9999L  0   6  12  18  24  30  36  42  48  54  60  66  72  78  84  90  96 102 108
     114 120 126 132 138 144
Surface wind stress - V     N/m**2
9999L  0   6  12  18  24  30  36  42  48  54  60  66  72  78  84  90  96 102 108
     114 120 126 132 138 144
-20 C isotherm pressure     Pa
8888   0   6  12  18  24  30  36
-20 C isotherm ICAO height    kft
8888   0   6  12  18  24  30  36
Freezing level ICAO height    kft
8888   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
Contrail lower limit     kft
8888   0  12  24  36  48
Contrail upper limit kft
8888   0  12  24  36  48
Maximum wind U-component    kn
8888   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
Maximum wind V-component     kn
8888   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
Maximum wind ICAO height    kft
8888   0   6  12  18  24  30  36  42  48  54  60
Tropopause ICAO height     kft
8888   0   6  12  18  24  30  36  42  48  54  60
Freezing level height    m
8888   0   6  12  18  24  30  36  42  48  54  60  66  72  78  84  90  96 102 108
     114 120 126 132 138 144
Tropopause pressure     Pa
8888   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
Tropopause temperature    K
8888   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
Tropopause height     m
8888   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
Maximum wind level pressure    Pa
8888   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
1.5 m temperature      K
9999   0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48  51  54
      57  60  63  66  69  72  78  84  90  96 102 108 114 120 126 132 138 144
Freezing-level pressure     Pa
8888   0   6  12  18  24  30  36  42  48  54  60  66  72  78  84  90  96 102 108
     114 120 126 132 138 144
Accumulated dynamic rain          kg/m**2
8888   0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48  51  54
      57  60  63  66  69  72  78  84  90  96 102 108 114 120 126 132 138 144
Accumulated convective rain       kg/m**2
8888   0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48  51  54
      57  60  63  66  69  72  78  84  90  96 102 108 114 120 126 132 138 144
Rate of dynamic rain              kg/m**2
```

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8888   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
Rate of convective rain            kg/m**2
8888   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
Accumulated dynamic snowfall       kg/m**2
8888   0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48  51  54
      57  60  63  66  69  72  78  84  90  96 102 108 114 120 126 132 138 144
Accumulated convective snowfall    kg/m**2
8888   0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48  51  54
      57  60  63  66  69  72  78  84  90  96 102 108 114 120 126 132 138 144
Rate of dynamic snowfall           kg/m**2
8888   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
Rate of convective snowfall        kg/m**2
8888   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
Topography      m
9999   0
10 m wind U-component      m/s
9999   0   1   2   3   4   5   6   7   8   9  10  11  12  15  18  21  24  27  30
      33  36  39  42  45  48  51  54  57  60  63  66  69  72  78  84  90  96 102
     108 114 120 126 132 138 144
10 m wind V-component      m/s
9999   0   1   2   3   4   5   6   7   8   9  10  11  12  15  18  21  24  27  30
      33  36  39  42  45  48  51  54  57  60  63  66  69  72  78  84  90  96 102
     108 114 120 126 132 138 144
High cloud amount          dimensionless
8888   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
Medium cloud amount        dimensionless
8888   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
Low cloud amount           dimensionless
8888   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
Convective cloud amount    dimensionless
8888   0   6  12  18  24  30  36  42  48  54  60  66  72  78  84  90  96 102 108
     114 120 126 132 138 144
Convective cloud base      Pa
8888   0   6  12  18  24  30  36  42  48  54  60  66  72  78  84  90  96 102 108
     114 120 126 132 138 144
Convective cloud top       Pa
8888   0   6  12  18  24  30  36  42  48  54  60  66  72  78  84  90  96 102 108
     114 120 126 132 138 144
Convective cloud base      kft
8888  18  24  30  36
Convective cloud top       kft
8888  18  24  30  36
Duct height      m
8888   0   6  12  18  24  30  36  42  48
Duct intensity (max. wavelength)      m
8888   0   6  12  18  24  30  36  42  48
Soil moisture content     Kg/m**2
9999   0   6
Snow depth  (water equivalent) Kg/m**2
9999   0   6  12  18  24
Sensible heat flux over sea      W/m**2
9999   0   6  12  18  24  30  36  42  48  54  60  66  72  78  84  90  96 102 108
```

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     114 120 126 132 138 144
 Evap-from-sea*leads/frac (amnt) Kg/m**2
 9999   0   6  12  18  24  30  36  42  48  54  60  66  72  78  84  90  96 102 108
     114 120 126 132 138 144
 Heat flux through sea ice*sif       W/m**2
 9999   0   6  12  18  24  30  36  42  48  54  60  66  72  78  84  90  96 102 108
     114 120 126 132 138 144
 Sea ice top melting ltnt heat flux     W/m**2
 9999   0   6  12  18  24  30  36  42  48  54  60  66  72  78  84  90  96 102 108
     114 120 126 132 138 144
 Sublimation from snow and sea ice
 9999   0   6  12  18  24  30  36  42  48  54  60  66  72  78  84  90  96 102 108
     114 120 126 132 138 144
 Total downward surface SW flux    W/m**2
 9999   0   6  12  18  24  30  36  42  48  54  60  66  72  78  84  90  96 102 108
     114 120 126 132 138 144
 Net down longwave radiation flux:open sea*sif    W/m**2
 9999   0   6  12  18  24  30  36  42  48  54  60  66  72  78  84  90  96 102 108
     114 120 126 132 138 144
 Sea-Ice cover            Fraction
 9999   0   6  12  18  24
 Total cloud, random overlap          range 0-1
 8888   0   6
 Total cloud, max/random overlap      range 0-1
 8888   0   6
 Incoming shortwave rad flux (TOA)   W/M**2
 8888   0   6  12  18  24  30  36  48  72  96 120 144
 Outgoing shortwave rad flux (TOA)   W/M**2
 8888   0   6  12  18  24  30  36  48  72  96 120 144
 Outgoing longwave rad flux (TOA)   W/M**2
 8888   0   6  12  18  24  30  36  48  72  96 120 144
 Upward short wave rad flux (TOA) Clear sky   W/m**2
 8888   0   6  12  18  24  30  36  48  72  96 120 144
 Upward long wave rad flux (TOA) Clear sky   W/m**2
 8888   0   6  12  18  24  30  36  48  72  96 120 144
 Downward longwave rad surface flux      W/m**2
 9999   0   6  12  18  24  30  36  48  72  96 120 144
 Water runoff           Kg/m**2
 9999   0   6  12  18  24  30  36  48  72  96 120 144
 Snow melt             KG/m**2
 9999   0   6  12  18  24  30  36  48  72  96 120 144
 Orographic roughness
 9999   0
 Soil type (hyrology param bs)
 9999   0   6
 Vegetation type
 9999   0   6
 PV on theta surface
  475   0      12      24             48             72      96
  425   0      12      24             48             72      96
  315   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
 UV index           0 - 12
```

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9999   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
Total Ozone (column)    Dobson
8888   0
UV index climatology    0 - 12
9999   0
Ozone climatology     Dobson
8888   0
Lowest Convective Cloud amount
8888   0   6  12  18 , 24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
Lowest Convective Cloud base      PA
8888   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
Lowest Convective Cloud top       PA
8888   0   6  12  18  24  30  36  42  48  54  60  66  72  84  96 108 120 132 144
```

LIMITED AREA MODEL (LAM)

Height m	Elapsed time of Forecasts (hours)																
1000	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
950	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
925	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
850	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
700	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
500	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
400	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
300	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
250	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
200	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
150	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
100	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
70	0	3															
50	0	3															
30	0	3															
Temperature K																	
1000	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
950	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
925	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
900	0		6		12		18		24		30		36		42		48
850	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
700	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
500	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
400	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
300	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
250	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
200	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
150	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
100	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
70	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
50	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
30	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
25	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
20	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
15	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
10	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
Wind U-component m/s																	
1000	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
950	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
925	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
900	0		6		12		18		24		30		36		42		48
850	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
700	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
600	0																
500	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
400	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
300	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
250	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
200	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
150	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48

100	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
70	0			3													
50	0			3													
30	0			3													
Wind V-component m/s																	
1000	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
950	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
925	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
900	0		6		12		18		24		30		36		42		48
850	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
700	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
600	0																
500	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
400	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
300	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
250	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
200	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
150	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
100	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
70	0			3													
50	0			3													
30	0			3													
Relative humidity (dimensionless), or mixing ratio kg/kg																	
9999	0	3															
1000	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
950	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
925	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
900	0		6		12		18		24		30		36		42		48
850	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
700	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
600	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
500	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
400	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
300	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
250	0	3															
200	0	3															
150	0	3															
100	0	3															
Vertical velocity Pa/s																	
1000	0	3															
950	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
925	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
850	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
700	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
500	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
250	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
200	0	3															
150	0	3															
100	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
70	0	3															
50	0	3															
30	0	3															

```
Mean sea level (8888) or surface (9999) pressure    Pa
8888   0   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
      19  20  21  22  23  24  25  26  27  28  29  30  31  32  33  34  35  36  39
      42  45  48
9999   0           3
Specific humidity at 1.5 m      dimensionless
9999   0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
Surface and B/lyr moisture flux (9999)      Kg/M**2/S
9999L  0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
Surface temperature    K
9999   0   3   6   9  12  15  18  21  24  27  30  33  36  42  48
Evaporation amount from soil surface (9999)   Kg/M**2
9999   0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
Wet-bulb potential temperature     K
 850   0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
 700   0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
 500   0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
Snow probability    dimensionless
8888   0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
-20DegC Isotherm True Ht     KFT
8888   0   6  12  18  24  30  36
Surface moisture flux over IREST t/s   kg/m**2 = mm/timeslic
9999   0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
Wind mixing     W/m**2
9999   0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
Latent heat flux     W/m**2
9999   0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
Sensible heat flux    W/m**2
9999L  0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
Net solar radiation flux top (8888) or bottom (9999) W/m**2
9999   0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
Net IR at top (8888) or bottom (9999)      W/m**2
9999   0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
Surface wind stress - U     N/m**2
9999L  0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
Surface wind stress - V     N/m**2
9999L  0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
Thermal advection    K/6 h
8888   0   6  12  18  24  30  36  42  48
-20 C isotherm pressure     Pa
8888   0   6  12  18  24  30  36
-20 C isotherm ICAO height    kft
8888   0   6  12  18  24  30  36
Freezing level ICAO height    kft
8888   0   6  12  18  24  30  36  42  48
Maximum wind U-component    kn
8888   0   3
Maximum wind V-component     kn
8888   0   3
Maximum wind ICAO height    kft
8888   0   3
Tropopause ICAO height     kft
```

```
8888   0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
Freezing level height    m
8888   0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
Tropopause pressure     Pa
8888   0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
Tropopause temperature    K
8888   0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
Tropopause height    m
8888   0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
Maximum wind level pressure    Pa
8888   0   3
1.5 m temperature      K
9999   0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
Freezing-level pressure     Pa
8888   0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
Accumulated dynamic rain          kg/m**2
8888   0   3   4   5   6   7   8   9  10  11  12  13  14  15  18  21  24  27  30
      33  36  39  42  45  48
Accumulated convective rain       kg/m**2
8888   0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
Rate of dynamic rain              kg/m**2
8888   0   3   4   5   6   7   8   9  10  11  12  13  14  15  18  21  24  27  30
      33  36  39  42  45  48
Rate of convective rain           kg/m**2
8888   0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
Accumulated dynamic snowfall      kg/m**2
8888   0   3   4   5   6   7   8   9  10  11  12  13  14  15  18  21  24  27  30
      33  36  39  42  45  48
Accumulated convective snowfall   kg/m**2
8888   0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
Rate of dynamic snowfall          kg/m**2
8888   0   3   4   5   6   7   8   9  10  11  12  13  14  15  18  21  24  27  30
      33  36  39  42  45  48
Rate of convective snowfall       kg/m**2
8888   0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
Topography     m
9999   0
10 m wind U-component     m/s
9999   0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
10 m wind V-component     m/s
9999   0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
50 m wind U-component     m/s
9999   0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
50 m wind V-component     m/s
9999   0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
High cloud amount        dimensionless
8888   0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
Medium cloud amount      dimensionless
8888   0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
Low cloud amount         dimensionless
8888   0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
Convective cloud amount     dimensionless
```

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8888   0   3   4   5   6   7   8   9  10  11  12  13  14  15  18  21  24  27  30
      33  36  39  42  45  48
Convective cloud base    Pa
8888   0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
Convective cloud top     Pa
8888   0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
Convective cloud base     kft
8888   0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
Convective cloud top      kft
8888   0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
Duct height     m
8888   0   6  12  18  24  30  36  42  48
Duct intensity (max. wavelength)     m
8888   0   6  12  18  24  30  36  42  48
Soil moisture content    Kg/m**2
9999   0   3
Sensible heat flux over sea     W/m**2
9999   0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
Evap-from-sea*leads/frac (amnt) Kg/m**2
9999   0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
Heat flux through sea ice*sif       W/m**2
9999   0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
Sea ice top melting ltnt heat flux     W/m**2
9999   0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
Sublimation from snow and sea ice
9999   0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
Total downward surface SW flux    W/m**2
9999   0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
Net down longwave radiation flux:open sea*sif    W/m**2
9999   0   3   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
Sea-Ice cover            Fraction
9999   0   3   6   9  12  15  18  21
Total cloud, random overlap          range 0-1
8888   0   3
Total cloud, max/random overlap      range 0-1
8888   0   3
Incoming shortwave rad flux (TOA)   W/M**2
8888   0   3   6   9  12  15  18  21  24  27  30  33  36
Outgoing shortwave rad flux (TOA)   W/M**2
8888   0   3   6   9  12  15  18  21  24  27  30  33  36
Outgoing longwave rad flux (TOA)   W/M**2
8888   0   3   6   9  12  15  18  21  24  27  30  33  36
Upward short wave rad flux (TOA) Clear sky   W/m**2
8888   0   3   6   9  12  15  18  21  24  27  30  33  36
Upward long wave rad flux (TOA) Clear sky   W/m**2
8888   0   3   6   9  12  15  18  21  24  27  30  33  36
Downward longwave rad surface flux      W/m**2
9999   0   3   6   9  12  15  18  21  24  27  30  33  36
Water runoff            Kg/m**2
9999   0   3   6   9  12  15  18  21  24  27  30  33  36
Snow melt              KG/m**2
9999   0   3   6   9  12  15  18  21  24  27  30  33  36
```

```
Orographic roughness
9999   0
Soil type (hyrology param bs)
9999   0   3
Vegetation type
9999   0   3
UV index            0 - 12
9999  12  36
Total Ozone (column)'    Dobson
8888  12
UV index climatology    0 - 12
9999   0
Ozone climatology     Dobson
8888   0
Lowest Convective Cloud amount
8888   0   3   4   5   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
Lowest Convective Cloud base      PA
8888   0   3   4   5   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
Lowest Convective Cloud top       PA
8888   0   3   4   5   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
Lowest Convective Cloud base      KFT
8888   0   3   4   5   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
Lowest Convective Cloud top       KFT
8888   0   3   4   5   6   9  12  15  18  21  24  27  30  33  36  39  42  45  48
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UK MESOSCALE

Height m	Elapsed time of Forecasts (hours)																	
1000	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
950	0			3			6			9			12			15			18
850	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
700	0			3			6			9			12			15			18
500	0			3			6			9			12			15			18
400	0			3			6			9			12			15			18
300	0			3			6			9			12			15			18
250	0			3			6			9			12			15			18
200	0			3			6			9			12			15			18
150	0			3			6			9			12			15			18
100	0			3			6			9			12			15			18
70	0			3			6			9			12			15			18
30	0			3			6			9			12			15			18
Temperature K																			
1000	0	3	6	9	12	15	18												
950	0	3	6	9	12	15	18												
850	0	3	6	9	12	15	18												
700	0	3	6	9	12	15	18												
500	0	3	6	9	12	15	18												
400	0	3	6	9	12	15	18												
300	0	3	6	9	12	15	18												
250	0	3	6	9	12	15	18												
200	0	3	6	9	12	15	18												
150	0	3	6	9	12	15	18												
100	0	3	6	9	12	15	18												
70	0	3	6	9	12	15	18												
30	0	3	6	9	12	15	18												
Wind U-component m/s																			
1000	0			3			6			9			12			15			18
950	0			3			6			9			12			15			18
850	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
700	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
500	0			3			6			9			12			15			18
400	0			3			6			9			12			15			18
300	0			3			6			9			12			15			18
250	0			3			6			9			12			15			18
200	0			3			6			9			12			15			18
150	0			3			6			9			12			15			18
100	0			3			6			9			12			15			18
70	0			3			6			9			12			15			18
30	0			3			6			9			12			15			18
Wind V-component m/s																			
1000	0			3			6			9			12			15			18
950	0			3			6			9			12			15			18
850	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
700	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
500	0			3			6			9			12			15			18
400	0			3			6			9			12			15			18
300	0			3			6			9			12			15			18
250	0			3			6			9			12			15			18

```
 200   0          3          6          9          12         15         18
 150   0          3          6          9          12         15         18
 100   0          3          6          9          12         15         18
  70   0          3          6          9          12         15         18
  30   0          3          6          9          12         15         18
Relative humidity (dimensionless), or mixing ratio  kg/kg
9999   0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18
1000   0          3          6          9          12         15         18
 950   0          3          6          9          12         15         18
 850   0          3          6          9          12         15         18
 700   0          3          6          9          12         15         18
 500   0          3          6          9          12         15         18
 400   0          3          6          9          12         15         18
 300   0          3          6          9          12         15         18
 250   0          3          6          9          12         15         18
 200   0          3          6          9          12         15         18
 150   0          3          6          9          12         15         18
 100   0          3          6          9          12         15         18
  70   0          3          6          9          12         15         18
  30   0          3          6          9          12         15         18
Fog Fraction at 1.5m
9999   0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18
Mean sea level (8888) or surface (9999) pressure    Pa
8888   0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18
Specific humidity at 1.5 m      dimensionless
9999   0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18
Boundary layer depth      m?
8888   0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18
Surface temperature    K
9999   0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18
Snow probability    dimensionless
8888   0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18
Sensible heat flux    W/m**2
9999L  0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18
Net solar radiation flux top (8888) or bottom (9999) W/m**2
9999   0  3  6  9 12 15 18
Surface wind stress - U     N/m**2
9999L  0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18
Surface wind stress - V     N/m**2
9999L  0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18
Freezing level ICAO height    kft
8888   0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18
Freezing level height    m
8888   0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18
1.5 m temperature       K
9999   0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18
Freezing-level pressure     Pa
8888   0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18
Accumulated dynamic rain          kg/m**2
8888   0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18
Accumulated convective rain       kg/m**2
8888   0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18
```

```
Rate of dynamic rain                    kg/m**2
8888   0   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
Rate of convective rain                 kg/m**2
8888   0   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
Accumulated dynamic snowfall            kg/m**2
8888   0   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
Accumulated convective snowfall         kg/m**2
8888   0   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
Rate of dynamic snowfall                kg/m**2
8888   0   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
Rate of convective snowfall             kg/m**2
8888   0   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
Topography      m
9999   0
10 m wind U-component       m/s
9999   0   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
10 m wind V-component       m/s
9999   0   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
High cloud amount          dimensionless
8888   0   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
Medium cloud amount        dimensionless
8888   0   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
Low cloud amount           dimensionless
8888   0   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
Convective cloud amount     dimensionless
8888   0   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
Convective cloud base     Pa
8888   0   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
Convective cloud top      Pa
8888   0   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
Convective cloud base     kft
8888   0   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
Convective cloud top      kft
8888   0   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
Cloud Fraction below 1000ft ASL
9999   0   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
Soil moisture content    Kg/m**2
9999   0   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
Snow depth  (water equivalent) Kg/m**2
9999   0   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
Visibility 1.5m          m
9999   0   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
Maximum screen temperature       K
9999   6  12  18
Minimum screen temperature       K
9999   6  12  18
Ht lowest cloud base > 0.1 okt      kft
8888   0   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
Ht lowest cloud base > 2.5 okt      kft
8888   0   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
Ht lowest cloud base > 4.5 okt      kft
8888   0   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
```

```
Ht lowest cloud base > 6.5 okt      kft
8888   0   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
Ht lowest cloud base > 7.9 okt      kft
8888   0   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
Canopy water near surface       Kg/m**2
8888   0   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
Roughness length              m
9999   0   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
Total cloud, random overlap           range 0-1
8888   0   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
Total cloud, max/random overlap       range 0-1
8888   0   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
Lowest Convective Cloud amount
8888   0   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
Lowest Convective Cloud base       PA
8888   0   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
Lowest Convective Cloud top        PA
8888   0   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
Lowest Convective Cloud base       KFT
8888   0   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
Lowest Convective Cloud top        KFT
8888   0   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
Probability of Visibility less than 5KM  0 - 1
9999   0   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
```

B PP-FORMAT FILES

This appendix deals with the format of pp-format files. Basically, a pp-format file is a FORTRAN-77 unformatted binary file, containing a 64-word file header, made up of 45 INTEGER*4 and 19 REAL*4 variables, followed by the data. The length of the data is specified in one of the integer variables (INTEGER_PP(15)). The date and time of the run are also specified in the integer header, as are codes specifying what the following data represents, be it velocities or vorticity or temperature or whatever. A data field is usually on a constant pressure surface so is two-dimensional, however data can also be on model η-levels or PV-surfaces or some other constant surface. The type of surface is specified in INTEGER_PP(16).

B.1 STASH and FIELD codes

The UM outputs a variety of parameters, which can be on a variety of levels, be it model η levels or pressure levels or PV-surfaces. Each parameter has two INTEGER codes associated with it, a **STASH** and a **FIELD** code. These codes are found in the INTEGER HEADER of the pp-format file. The STASH code is INTEGER_PP(42) and FIELD code is INTEGER_PP(23).

STASH codes for parameters are grouped according to sections of the UM, while FIELD codes can be for parameters that are not used by the UM. In some cases, FIELD codes are not unique, so it is preferable to use the STASH codes. JPLOT (Section 10.1) uses the STASH code to identify a field from the pp-format file header.

B.2 Format of the pp-format file header

```
  Listed below are details of the format of the 64-word header required
for any field in 'PP-format'.

  1  LBYR      Year  (eg 1986 or 86) \
  2  LBMON     Month          (1-12)  |  Validity time of field,
  3  LBDAT     Day of month   (1-31)  |            - or -
  4  LBHR      Hour           (0-23)  |  Start of averaging period (for time
  5  LBMIN     Minute         (0-59)  |  mean fields).
  6  LBDAY     Day number of run     /

  7  LBYRD     Year  (eg 1986 or 86) \
  8  LBMOND    Month          (1-12)  |  Data time (for forecast fields),
  9  LBDATD    Day of month   (1-31)  |            - or -
 10  LBHRD     Hour           (0-23)  |  End of averaging period (for time
 11  LBMIND    Minute         (0-59)  |  mean fields).
 12  LBDAYD    Day number of run     /

 13  LBTIM     Time indicator.  This indicates what the times in words 1-12
               represent.  Referring to the times represented by words 1-6 and
               7-12 as 'T1' and 'T2' respectively, LBTIM is coded as
               (100*IA + 10*IB + IC) where:

                 IA = 0  except for time mean fields in which case IA
                         is the time interval in hours between the
                         individual fields from which the mean was
                         computed (IA may be left as zero for
                         time-means to indicate that the time interval
                         is unspecified).
```

IB = 0 if only the validity time (T1) is valid.
= 1 if the field is a forecast from T2 valid at T1.
= 2 if the field is a time mean between T1 and T2, or represents a sequence of times between T1 and T2.
= 3 if the field is a time mean from T1 to T2 for each year from LBYR to LBYRD.
= 4 if the field is a difference between fields valid at T1 and T2 (in sense T2-T1).
= 5 if the field is a mean daily cycle between T2 and T1

IC = 0 if 'model time' is used for T1 and T2 (i.e. only day number, hour and minute are set).
= 1 if the 'real' (i.e. Gregorian) calendar is used for T1 and T2.
= 2 if the '360-day' year calendar (i.e. 12 30-day months) is used for T1 and T2. (This is used in Met.0.20 for some model runs.)
= 3 if 'model time' is used for T1 and T2 (i.e. only day number, hour and minute are valid; year, month and day in month are to be ignored if set).

'IC' corresponds to the parameter MCAL in COMCON.
If 'IC' is 1 or 2, coding of the 'day numbers' (words 6 and 12) is optional: code as 0 if not used.

14 LBFT Forecast period (hours).

15 LBLREC Length of data record in words (including any 'extra data').

16 LBCODE Grid code. This indicates the type of grid and is coded as:

1 Regular latitude/longitude grid.
2 Regular lat/long grid boxes (grid points are box centres).
3 Polar stereographic grid.
4 Spectral coefficients.
7 Mercator grid.
8 Plane polar grid.
9 Plane Cartesian grid.

For grids with non-standard polar axis, add 100 to the above numbers.

For cross sections, code as (10000 + 100*IX + IY) where IX and IY are codes for the x- and y-axes from the list below. Cross section fields indicated in this way must contain x- and y-coordinate vectors in the extra data. When LBCODE is coded as 30000 + 100*IX + IY, with IX and IY from the same list, the axes are given the same interpretation as for a normal cross section, but coordinate vectors need not be supplied. In this

case, however, the field is not regarded as a cross section by PP cross-section routines.

Axis codes are as follows:

0 Sigma (or eta, for hybrid coordinate data).
1 Pressure (mb).
2 Height above sea level (km).
3 Eta (U.M. hybrid coordinates) only.
4 Depth below sea level (m).
5 Model level.
6 Theta.
7 Sigma only.
10 Latitude (degrees N).
11 Longitude (degrees E).
12 (Horizontal) distance (km).
13 Site number (set of parellel rows or columns eg timeseries)
20 Time (days). (Gregorian calendar (not 360 day year) if distinction applicable)
21 Time (months).
22 Time (years).
23 Time (model days with 360 day model calendar)
31 Logarithm to base 10 of pressure in mb.
40 Pseudolevel
99 Other.

17 LBHEM Hemisphere indicator. For geographical grids (lat/long, polar stereographic, Mercator or 'Kurihara' grids), this is coded as:

0 Global field (i.e. covering the WHOLE globe).
1 Northern hemisphere polar stereographic grid, or other geographic grid covering the WHOLE northern hemisphere.
2 Southern hemisphere polar stereographic grid, or other geographic grid covering the WHOLE southern hemisphere.
3 Limited area of globe without 'wrap-around' (i.e. NOT covering the full 360-degree longitude range).
4 Limited area of globe with 'wrap-around' (i.e. covering the full 360-degree longitude range).

For SPECTRAL COEFFICIENTS, code 0, 1 or 2 as appropriate.
For CROSS-SECTION FIELDS, a value of 3 should be coded.
For GRAPH FIELDS, a value of 5 should be coded.
For LATERAL BOUNDARY DATA a value of 99 should be coded.

18 LBROW Number of rows in field.
(For spectral coefficients, code the 'n' truncation level.)

19 LBNPT Number of grid points in each row.
(For staggered grids, code values appropriate for the longest row. For spectral coefficients, code the 'm' truncation level.)

20 LBEXT Length of 'extra data' (x- and y-vectors for cross sections, and field title if any) in words.

21 LBPACK Packing method indicator (for fields in packed format.)

0	Field not packed
1	Field packed using WGDOS archive method
2	(Reserved for GRIB code data)
2000	unpacked Cray data
2001	packed Cray data

22 LBREL Header release number. (Set to 2 for format described here.)

23 LBFC Field code. This indicates what the data in the field represents Some of the more common field codes are listed below.

1	Height field	73	Relative vorticity field
8	Pressure field	74	Divergence field
16	Temperature field	88	Relative humidity field
40	Vertical velocity (dp/dt)	90	Total Precipitation
56	Westerly wind component	95	Specific humidity field
57	Southerly wind component		

24 LBCFC Second field code. This is only used for a field which is a combination of two field types; for example, a meridional temperature flux field (a product of V and T). Coding is as for the field code above.

25 LBPROC Processing code. This indicates what processing has been done to the basic field. It should be 0 if no processing has been done: otherwise add together the relevant numbers from the list below:

1	Difference from another experiment.
2	Difference from zonal (or other spatial) mean.
4	Difference from time mean.
8	X-derivative (d/dx).
16	Y-derivative (d/dy).
32	Time derivative (d/dt).
64	Zonal mean (or spatially smoothed) field.
128	Time mean field.
256	Product of two fields.
512	Square root of a field.
1024	Difference between fields at levels BLEV and BRLEV.
2048	Mean over layer between levels BLEV and BRLEV.
4096	Minimum value of field during time period.
8192	Maximum value of field during time period.
16384	Magnitude of a vector, not specifically wind speed
32768	log10 of a field.
65536	Variance of a field.
131072	Mean over an ensemble of parallel runs.

(For details of BLEV and BRLEV, see words 32 and 33.)

26 LBVC Vertical co-ordinate type. The 'vertical co-ordinate' is the one which has the same value at every grid point; e.g. 'pressure' for a 500mb height field or 'longitude' for a zonal mean cross section. The co-ordinate type is coded using the table of field codes as for word 23. Numbers 126-139 are used for special levels. The most common vertical co-ordinate types are:

1	Height (m)	8	Pressure (mb)
9	Hybrid co-ordinates	10	Sigma (=p/p*)
128	Mean sea level	129	Surface
130	Tropopause level	131	Maximum wind level
132	Freezing level	142	Upper hybrid level
143	Lower hybrid level	176	Latitude (deg)
177	Longitude (deg)		

27 LBRVC Vertical co-ordinate type for reference level. Used only when a reference level is applicable as in thickness fields or layer mean fields. Coded as above.
Set to 0 by the U.M. if no reference level.

28 LBEXP Experiment number (optional parameter for user's reference only).
In Operational use this is set to the ITAB number:

1 Global main run data
2 Global update run data
3 Limited-area main run data
4 ECMWF data
5 Washington data
6 Limited-area update run data
7 Global wave data
8 European wave data
9 UK Mesoscale model main runs
(Formerly limited-area SIGMA/ETA data (obsolete))
10 Paris data

21 Bosnia Mesoscale model runs
22 Gulf Mesoscale model runs
23 Stratospheric model runs
24 Short term Mesoscale models
25 FOAM model runs

29 LBEGIN (For fields on direct access datasets only) Address of start of field in direct access dataset.

30 LBNREC (For fields on direct access datasets only) Number of records occupied by field on direct access dataset.

31 LBPROJ (For Met Office fields file use) Fields file projection number.
32 LBTYP (For Met Office fields file use) Fields file field type code.

33 LBLEV (For Met Office fields file use) Fields file level code. 7777 = multi-level field in lateral boundary data.

34-37 LBRSVD(4) Reserved for future PP-package use.

38 LBSRCE In Met Office Unified Model, set to 1111 to indicate items 39-43 are in use as below. Otherwise, spare for user's use.

39 LBUSER(1) In Met. Office Unified Model, Indicator for real/integer/logical/land points only/ timeseries 1=real data for all output fields; fields of INTEGER/LOGICAL type will not be available until further development work on the diagnostic system is undertaken, as FIELDCOS does not handle them.

40 LBUSER(2) In Met. Office Unified Model, Start address in DATA

41 LBUSER(3) In Met. Office Unified Model, For timeseries - number of sampling periods

42 LBUSER(4) In Met. Office Unified Model, the STASH code

43 LBUSER(5) In Met. Office Unified Model, Timeseries indicator 1=data is timeseries 0=not (STASH pseudo dimension)

44 LBUSER(6) No present use - spare for user's use, as are items 39-43 outside the Met. Office Unified Model. See also UM Documentation Paper F3.

45 LBUSER(7) As 44. Note: there is presently an ambiguity in the Met.Office Unified Model about the type of item 45. Dumps and PP fields within the model define the first 45 items as integer and items 46 onwards as real. The integer array LBUSER is equivalenced to a real array BUSER.

46-49 BRSVD(4) Reserved for future PP-package use.

50 BDATUM Constant value subtracted from each value in field. This is usually zero but would be 273.15 for a temperature field in degrees Celsius.

51 BACC (Packed fields only) Packing accuracy.

52 BLEV Level. This is the value of the vertical co-ordinate LBVC (word 26) appropriate for the field; e.g. '500.0' for a 500 mb height field. For hybrid levels code the 'B'-value of the level. BLEV should be zero if the vertical co-ordinate type is in the range 128 to 139.

53 BRLEV Reference level. This is the value of the vertical co-ordinate

LBRVC (word 27) appropriate for the field. It is used when a second level is relevant as for example with thickness fields when the 'reference level' should be the one nearest the ground. Code as for BLEV.

54 BHLEV (Hybrid levels) 'A'-value of level.
55 BHRLEV (Hybrid levels) 'A'-value of reference level.

56 BPLAT Real latitude of 'pseudo' N pole of projection. Code as '90.0' for fields on grid with normal polar axis.
57 BPLON Real longitude of 'pseudo' N pole of projection. Code as '0.0' for fields on grid with normal polar axis.

58 BGOR \
59 BZY | These five parameters define the grid for the field.
60 BDY | The coding depends on what type of grid the field is on.
61 BZX | Details for various types follow:
62 BDX /

(i) Latitude/longitude grids.

BGOR Not used - set to zero.
BZY Latitude of 'zeroth' row (i.e. an imaginary row one grid length before the first row) in degrees (north positive).
BDY Latitude interval between rows in degrees (negative if rows are north to south).
BZX Longitude of 'zeroth' point in row (i.e. an imaginary point one grid length before the first point) in degrees (east positive).
BDX Longitude spacing of points in each row in degrees (negative if points run from east to west).

(ii) Polar stereographic grids.

BGOR Grid orientation. This is the longitude in degrees of the meridian which would be vertical with north at the top on a chart drawn for the grid.
BZY Reference latitude in degrees (see BDY).
BDY Grid length in metres at reference latitude.
BZX 'X' co-ordinate of the pole.
BDX 'Y' co-ordinate of the pole.
These co-ordinates are in grid lengths (not necessarily whole numbers and not necessarily representing a point within the area covered by the grid) counting the bottom left grid point of a chart as the point (1.0, 1.0).

(iii) Mercator grids.

For Mercator grids, the coding is the same as in (i) except that BZY and BDY are values of:

(earth's radius) * log((1+sin(latitude))/cos(latitude))

instead of latitude. (The earth's radius is in metres and 'log' refers to the natural logarithm.)

(iv) Cross sections.
~~~~~~~~~~~~~~~~~~~~ For cross-section grids, coding is as in (i) above except that BZY and BDY are values of the 'y' co-ordinate and BZX and BDX are values of the 'x' co-ordinate. (Note that for zonal mean fields or cross sections along a meridian, BZX and BZY are longitudes.) If the cross section is on irregularly spaced levels, BZY and BDY should both be zero.

(v) Graph fields.
~~~~~~~~~~~~~~~~~ For graph fields, coding is as in (i) above except that BZX and BDX are values of the 'x' co-ordinate, and BDY and BZY are both coded as 1.0. If points on the graphs are not evenly spaced in the 'x' co-ordinate, BZX and BDX should both be coded as zero.

(vi) Spectral coefficients.
~~~~~~~~~~~~~~~~~~~~~~~~~~

BGOR Not used - coded as zero.
BZY Not used - coded as zero.
BDY Not used - coded as zero.
BZX Reference longitude - usually 0.0. This is the meridian which is treated as the origin of longitude for the coefficients.
BDX Not used - coded as zero.

63 BMDI Value used in the field to indicate missing data points. If the field contains no missing data, code a value of -1.0E30.

64 BMKS MKS scaling factor, equal to the size of the unit in which the field is expressed divided by the corresponding mks unit. (e.g. 10.0 for height in dam, 100.0 for pressure in mb, 0.01 for relative humidity in % etc.).
~~~~~~~~~~~~~~~~~~~~~~~~~~

C OUTPUT UM FIELDS AND STASH CODES

Stash	Code	Field
0	1	PSTAR AFTER TIMESTEP
0	2	U COMPNT OF WIND AFTER TIMESTEP
0	3	V COMPNT OF WIND AFTER TIMESTEP
0	,4	THETA AFTER TIMESTEP
0	5	THETAL IN THE EXTERNAL DUMP
0	9	SOIL MOISTURE CONTENT IN A LAYER
0	10	SPECIFIC HUMIDITY AFTER TIMESTEP
0	11	QT IN THE EXTERNAL DUMP
0	13	CONV CLOUD AMOUNT AFTER TIMESTEP
0	14	CONV CLOUD BASE LEVEL NO. AFTER TS
0	15	CONV CLOUD TOP LEVEL NO. AFTER TS
0	16	CONV CLOUD LIQUID WATER PATH
0	17	SILHOUETTE OROGRAPHIC ROUGHNESS
0	18	HALF OF (PEAK TO TROUGH HT OF OROG)
0	19	STANDARD OROGRAPHIC ROUGHNESS
0	20	DEEP SOIL TEMP AFTER TIMESTEP
0	21	SOIL MOISTURE CONTENT AFTER TS KG/M2
0	22	CANOPY WATER AFTER TIMESTEP KG/M2
0	23	SNOW AMOUNT AFTER TIMESTEP KG/M2
0	24	SURFACE TEMPERATURE AFTER TIMESTEP
0	25	BOUNDARY LAYER DEPTH AFTER TIMESTEP
0	26	ROUGHNESS LENGTH AFTER TIMESTEP
0	27	SNOW EDGE AFTER TIMESTEP
0	28	SURFACE ZONAL CURRENT AFTER TIMESTEP
0	29	SURFACE MERID CURRENT AFTER TIMESTEP
0	30	LAND MASK (LOGICAL: LAND=TRUE)
0	31	SEA ICE FRACTION AFTER TIMESTEP
0	32	SEA ICE DEPTH (MEAN OVER ICE)
0	33	OROGRAPHY (/STRAT LOWER BC)
0	34	STANDARD DEVIATION OF OROGRAPHY
0	35	OROGRAPHIC GRADIENT XX COMPONENT
0	36	OROGRAPHIC GRADIENT XY COMPONENT
0	37	OROGRAPHIC GRADIENT YY COMPONENT
0	38	ICE EDGE AFTER TIMESTEP
0	39	SST ANOMALY

Table 6: Potential output from the UM. Stash codes are calculated by multiplying the stash section number by 1000 and adding the section code e.g. DEEP SOIL TEMP AFTER TIMESTEP 0x1000+20 = 00020

Stash	Code	Field
0	40	VOL SMC AT WILTING AFTER TIMESTEP
0	41	VOL SMC AT CRIT PT AFTER TIMESTEP
0	42	VOL SMC AT FIELD CAP AFTER TIMESTEP
0	43	VOL SMC AT SATURATION AFTER TIMESTEP
0	44	SAT SOIL CONDUCTIVITY AFTER TIMESTEP
0	45	EAGLESON'S EXPONENT AFTER TIMESTEP
0	46	THERMAL CAPACITY AFTER TIMESTEP
0	47	THERMAL CONDUCTIVITY AFTER TIMESTEP
0	48	SATURATED SOIL WATER SUCTION
0	49	SEA-ICE TEMPERATURE AFTER TIMESTEP
0	50	VEGETATION FRACTION AFTER TIMESTEP
0	51	ROOT DEPTH AFTER TIMESTEP
0	52	SNOW-FREE SURFACE ALBEDO AFTER TS
0	53	DEEP SNOW SURFACE ALBEDO AFTER TS
0	54	SURFACE RESISTANCE TO EVAP AFTER TS
0	55	SURFACE CAPACITY AFTER TIMESTEP
0	56	INFILTRATION FACTOR AFTER TIMESTEP
0	57	TOTAL AEROSOL EMISSIONS (FOR VIS)
0	58	SULPHUR DIOXIDE EMISSIONS
0	59	DIMETHYL SULPHIDE EMISSIONS
0	60	OZONE
0	61	ATM TRACER 1 (CONVEN O3)AFTER TS
0	62	ATM TRACER 2 (CONVEN H2O)AFTER TS
0	63	ATM TRACER 3 (CONVEN CO)AFTER TS
0	64	ATM TRACER 4 (CONVEN CH4)AFTER TS
0	65	ATM TRACER 5 (CONVEN N2O)AFTER TS
0	66	ATM TRACER 6 (CONVEN NO)AFTER TS
0	67	ATM TRACER 7 (CONVEN NO2)AFTER TS
0	68	ATM TRACER 8 (CONVEN HNO3)AFTER TS
0	69	ATM TRACER 9 (CONVEN N2O5)AFTER TS
0	70	ATM TRACER 10 (CONVN CLONO2)AFTER TS
0	71	ATM TRACER 11 (CONVEN CLO)AFTER TS
0	72	ATM TRACER 12 (CONVEN HCL)AFTER TS
0	73	ATM TRACER 13 (CONVN CF2CL2)AFTER TS
0	74	ATM TRACER 14 (CONVEN CFCL3)AFTER TS
0	75	ATM TRACER 15 (CONVEN HF)AFTER TS
0	76	ATM TRACER 16 (CONVEN —)AFTER TS
0	77	ATM TRACER 17 (CONVEN —)AFTER TS
0	78	ATM TRACER 18 (CONVEN —)AFTER TS
0	79	ATM TRACER 19 (CONVEN SO2)AFTER TS
0	80	ATM TRACER 20 (CONVEN DMS)AFTER TS
0	81	ATM TRACER 21 (CONVEN H2S)AFTER TS
0	82	ATM TRACER 22 (CONV WATER-SOL)AFT TS
0	83	ATM TRACER 23 (CONV "DUST")AFTER TS
0	84	ATM TRACER 24 (CONV OCEANIC)AFTER TS
0	85	ATM TRACER 25 (CONVEN SOOT)AFTER TS
0	86	ATM TRACER 26 (CONV VOLC ASH) AFT TS

Stash	Code	Field
0	87	ATM TRACER 27 (CONVEN H2SO4)AFTER TS
0	88	ATM TRACER 28 (NH4)2SO4 AFTER TS
0	89	ATM TRACER 29 (CONV MINERAL)AFTER TS
0	90	TOTAL AEROSOL (FOR VISIBILITY)
0	93	RUNOFF COASTAL OUTFLOW POINT
0	96	HORIZ BOUNDARY TENDS: UNAVAILABLE
0	97	HORIZ BOUNDARY VALUES: UNAVAILABLE
0	98	LOWER BOUNDARY TENDENCIES (OROG)
0	101	POTENTIAL TEMPERATURE (OCEAN) DEG.C
0	102	SALINITY (OCEAN) (PSU-35)/
0	103	OCN EXTRACER 1: CONVEN TCO2
0	104	OCN EXTRACER 2: CONVEN ALAKLINITY
0	105	OCN EXTRACER 3: CONVEN NUTRIENT
0	106	OCN EXTRACER 4: CONVEN PHYTOPLNKTN
0	107	OCN EXTRACER 5: CONVEN ZOOPLNKTN
0	108	OCN EXTRACER 6: CONVEN DETRITUS
0	109	OCN EXTRACER 7: CONVEN TRITIUM
0	110	OCN EXTRACER 8: CONVEN 3H+3HE
0	111	OCN EXTRACER 9: CONVEN CFC11
0	112	OCN EXTRACER 10: CONVEN CFC12
0	113	OCN EXTRACER 11: CONVEN CFC13
0	114	OCN EXTRACER 12: CONVEN CARBON14
0	115	OCN EXTRACER 13: CONVEN ——
0	116	OCN EXTRACER 14: CONVEN ——
0	117	OCN EXTRACER 15: CONVEN ——
0	118	OCN EXTRACER 16: CONVEN ——
0	119	OCN EXTRACER 17: CONVEN ——
0	120	OCN EXTRACER 18: CONVEN ——
0	121	BAROCLINIC U_VELOCITY (OCEAN) CM/S
0	122	BAROCLINIC V_VELOCITY (OCEAN) CM/S
0	130	STREAMFUNCTION (OCEAN) CM3/S
0	131	STREAMFUNCTION (T-1) (OCEAN) CM3/S
0	132	STREAMFN TENDENCY (OCEAN) CM3/S/TS
0	133	STREAMFN TENDENCY(T-1)(OCN) CM3/S/TS
0	134	SURFACE ELEVATION (OCEAN) CM
0	135	BAROTROPIC U_VELOCITY (OCEAN) CM/S
0	136	BAROTROPIC V_VELOCITY (OCEAN) CM/S
0	137	MIXED LAYER DEPTH (OCEAN) M
0	139	ISX X OCEAN/ICE STRESS (ICE) N/M2
0	140	ISY Y OCEAN/ICE STRESS (ICE) N/M2
0	141	SNOW DEPTH (OCEAN) M
0	142	GBM CARYHEAT MISC HEAT FLX(ICE) W/M2
0	143	GBM HEAT FLUX:OCEAN TO ICE(OCN) W/M2
0	144	RATE OF SALINITY CHANGE (ICE) PSU/S

Stash	Code	Field
0	145	ICY : TRUE IF BOX CONTAINS ICE
0	146	AICE : ICE CONCENTRATION
0	147	HICE: MEAN ICE DEPTH OVER GRIDBOX M
0	148	ICE U_VELOCITY M/S
0	149	ICE V_VELOCITY M/S
0	150	TAUX: X_WINDSTRESS N/M2 A
0	151	TAUY: Y_WINDSTRESS N/M2 A
0	152	WME: WIND MIXING ENERGY FLUX W/M2 A
0	153	SURFACE PRESSURE N/M2 A
0	161	SOL: PEN.SOLAR*LF INTO OCEAN W/M2 A
0	162	HTN:NONPEN.HT.FLX*LF INTO OCN W/M2 A
0	165	PLE:PRECIP-EVAP INTO OCEAN KG/M2/S A
0	166	RIVER OUTFLOW INTO OCEAN KG/M2/S A
0	167	WATER TYPE A
0	170	SOLAR RADIATION OVER ICE W/M2 A
0	171	SNOWFALL INTO OCN/ONTO ICE KG/M2/S A
0	172	SUBLIMATION FROM SEAICE KG/M2/S A
0	175	LAT B'DARY CONDITIONS (BOUNDARY)
0	176	LAT B'DARY TENDENCIES (BOUNDARY)
0	177	HEAT CONVERGENCE (SLAB MODEL) W/M2 A
0	178	REF. SEA SURF TEMP (SLAB MODEL) K A
0	179	CLIM. SEAICE DEPTH (SLAB MODEL) M A
0	180	REF. SEA SURF. TEMPERATURE DEG.C A
0	181	REF.SEA SURF.SALINITY(PSU-35)/ A
0	182	CLIM. AIR TEMPERATURE DEG.C A
0	183	CLIMATOLOGICAL ICE DEPTH M A
0	185	OCEAN HEAT FLUX CORRECTION W/M2 A
0	186	P-E FLUX CORRECTION KG/M2/S A
0	190	GBM SEAICE TOPMELT HEAT FLUX W/M2 A
0	191	GBM SEAICE BOTMELT HEAT FLUX W/M2 A
0	201	PSTAR PERTURBATION- DUMMY
0	202	U COMPNT PERTURBATION- DUMMY
0	203	V COMPNT PERTURBATION- DUMMY
0	204	THETA PERTURBATION- DUMMY
0	205	FRACTIONAL LAND COVER
0	210	SLAB TEMPERATURE AFTER TSTEP SLAB C
0	211	UICE ICE VELOCITY SLAB M/S
0	212	VICE ICE VELOCITY SLAB M/S
1	4	TEMPERATURE AFTER SW RAD INCREMENTS
1	201	NET DOWN SURFACE SW FLUX: SW TS ONLY
1	202	NET DOWN SW FLUX: SOLID SURF: ALL TS
1	203	NET DOWN SW RAD FLUX: OPEN SEA
1	204	NET DOWN SW RAD FLUX:OPEN SEA:BAND 1
1	205	SNOW-FREE SURFACE ALBEDO (ANCILLARY)

Stash	Code	Field
1	206	DEEP SNOW SURFACE ALBEDO (ANCILLARY)
1	207	INCOMING SW RAD FLUX (TOA): ALL TSS
1	208	OUTGOING SW RAD FLUX (TOA)
1	209	CLEAR-SKY (II) UPWARD SW FLUX (TOA)
1	210	CLEAR-SKY (II) DOWN SURFACE SW FLUX
1	211	CLEAR-SKY (II) UP SURFACE SW FLUX
1	212	LAYER CLOUD WEIGHTS IN SWRAD
1	213	CONVECTIVE CLOUD WEIGHTS IN SWRAD
1	214	LAYER CLOUD DIRECT ALBEDO * AMOUNT
1	215	LAYER CLOUD DIFFUSE ALBEDO * AMOUNT
1	216	CONV CLOUD DIRECT ALBEDO * AMOUNT
1	217	CONV CLOUD DIFFUSE ALBEDO * AMOUNT
1	218	LAYER CLOUD REDUCED TO 3 LAYERS - SW
1	219	TOTAL CLOUD AMOUNT IN SW RADIATION
1	220	CONV CLD LIQ RE * CONV CLD AMOUNT
1	221	LAYER CLD LIQ RE * LAYER CLD AMOUNT
1	222	CONV CLD AMT IN SWRAD (MICROPHYSICS)
1	223	LYR CLD AMT IN SWRAD (MICROPHYSICS)
1	224	LAYER CLD CONDENSED WATER PATH * AMT
1	225	CONV CLD LIQ RE * CONV CLD WEIGHT
1	226	CONV CLD WGT IN SWRAD (MPHY ALL LYR)
1	232	SW HEATING RATES: ALL TIMESTEPS
1	233	CLEAR-SKY SW HEATING RATES
1	235	TOTAL DOWNWARD SURFACE SW FLUX
2	4	TEMPERATURE AFTER LW RAD INCREMENTS
2	201	NET DOWN SURFACE LW RAD FLUX
2	202	NET DOWN LW RAD FLUX: SOLID SURFACE
2	203	NET DOWN LW RAD FLUX: OPEN SEA
2	204	TOTAL CLOUD AMOUNT IN LW RADIATION
2	205	OUTGOING LW RAD FLUX (TOA)
2	206	CLEAR-SKY (II) UPWARD LW FLUX (TOA)
2	207	DOWNWARD LW RAD FLUX: SURFACE
2	208	CLEAR-SKY (II) DOWN SURFACE LW FLUX
2	232	LW HEATING RATES
2	233	CLEAR-SKY LW HEATING RATES
3	2	U COMPNT OF WIND AFTER B.LAYER
3	3	V COMPNT OF WIND AFTER B.LAYER
3	4	TEMPERATURE AFTER B.LAYER
3	10	SPECIFIC HUMIDITY AFTER B.LAYER
3	24	SURFACE TEMPERATURE AFTER B.LAYER
3	25	BOUNDARY LAYER DEPTH AFTER B.LAYER
3	26	ROUGHNESS LEN. AFTER B.L.
3	49	SEA-ICE TEMPERATURE AFTER B. LAYER
3	100	FLUX OF TRACER 1 IN BL

Stash	Code	Field
3	101	FLUX OF TRACER 2 IN BL
3	102	FLUX OF TRACER 3 IN BL
3	103	FLUX OF TRACER 4 IN BL
3	104	FLUX OF TRACER 5 IN BL
3	105	FLUX OF TRACER 6 IN BL
3	106	FLUX OF TRACER 7 IN BL
3	107	FLUX OF TRACER 8 IN BL
3	108	FLUX OF TRACER 9 IN BL
3	109	FLUX OF TRACER 10 IN BL
3	110	FLUX OF TRACER 11 IN BL
3	111	FLUX OF TRACER 12 IN BL
3	112	FLUX OF TRACER 13 IN BL
3	113	FLUX OF TRACER 14 IN BL
3	114	FLUX OF TRACER 15 IN BL
3	115	FLUX OF TRACER 16 IN BL
3	116	FLUX OF TRACER 17 IN BL
3	117	FLUX OF TRACER 18 IN BL
3	118	FLUX OF TRACER 19 IN BL
3	119	FLUX OF TRACER 20 IN BL
3	120	FLUX OF TRACER 21 IN BL
3	121	FLUX OF TRACER 22 IN BL
3	122	FLUX OF TRACER 23 IN BL
3	123	FLUX OF TRACER 24 IN BL
3	124	FLUX OF TRACER 25 IN BL
3	125	FLUX OF TRACER 26 IN BL
3	126	FLUX OF TRACER 27 IN BL
3	127	FLUX OF TRACER 28 IN BL
3	128	FLUX OF TRACER 29 IN BL
3	129	FLUX OF TOTAL AEROSOL IN BL
3	201	HEAT FLUX THROUGH SEA ICE (GBM) W/M2
3	202	HT FLUX FROM SURF TO DEEP SOIL LEV 1
3	203	CD
3	204	CH
3	205	SURFACE LAYER WIND SHEAR
3	206	RHOSTAR * CD * SURF_LAYER_WIND_SHEAR
3	207	RHOSTAR * CH * SURF_LAYER_WIND_SHEAR
3	208	LOWEST LAYER BULK RICHARDSON NO. RIB
3	209	CD (OPEN SEA VALUE AT SEA ICE PTS)
3	210	CH (OPEN SEA VALUE AT SEA ICE PT)
3	211	CD (M.ICE ZONE VALUE AT SEA ICE PT)
3	212	CH (M.ICE ZONE VALUE AT SEA ICE PT)
3	213	CD (COMPLETE SEAICE VALUE@SEAICE PT)
3	214	CH (COMPLETE SEAICE VALUE@SEAICE PT)
3	215	RIB SURFACE LAYER (LEADS)

Stash	Code	Field
3	216	RIB SURFACE LAYER (SEA ICE)
3	217	SURFACE & B.LAYER HEAT FLUXES W/M2
3	219	X-COMP OF SURF & BL WIND STRESS N/M2
3	220	Y-COMP OF SURF & BL WIND STRESS N/M2
3	223	SURF & BL TOTL MOISTURE FLUX KG/M2/S
3	224	WIND MIXING EN'GY FLUX INTO SEA W/M2
3	225	10 METRE WIND U-COMP
3	226	10 METRE WIND V-COMP
3	227	SURFACE SH FLUX FROM LEADS(GBM) W/M2
3	228	SURFACE SH FLUX FROM SEA (GBM) W/M2
3	229	EVAP FROM SOIL SURF -AMOUNT KG/M2/TS
3	230	EVAP FROM CANOPY - AMOUNT KG/M2/TS
3	231	SUBLIM. FROM SURFACE (GBM) KG/M2/TS
3	232	EVAPORATION FROM SEA (GBM) KG/M2/S
3	234	SURFACE LATENT HEAT FLUX W/M2
3	235	SEAICE TOP MELTING LH FLUX(GBM) W/M2
3	236	TEMPERATURE AT 1.5M
3	237	SPECIFIC HUMIDITY AT 1.5M
3	238	DEEP SOIL TEMPERATURE AFTER B.LAYER
3	239	CLOUD LIQUID WATER AFTER B.LAYER
3	240	CLOUD ICE CONTENT AFTER B.LAYER
3	241	TOTAL SURF MOIST FLUX PER TIMESTEP
3	242	CLOUD FRACTION AT 1.5M
3	243	CLOUD LIQUID WATER AT 1.5M
3	244	CLOUD ICE CONTENT AT 1.5M
3	245	RELATIVE HUMIDITY AT 1.5M
3	246	OROGRAPHIC ROUGHNESS
3	247	VISIBILITY AT 1.5M M
3	248	FOG FRACTION AT 1.5 M
3	249	10 METRE WIND SPEED M/S
3	250	DEWPOINT AT 1.5M (K)
3	251	SILHOUETTE OROGRAPHIC ROUGHNESS
3	252	HALF OF (PEAK TO TROUGH HT OF OROG)
3	253	PROBABILITY OF VIS LESS THAN 5 KM
3	254	TL AT 1.5M
3	255	QT AT 1.5M
3	256	RHO_CD_MODV1
3	257	RHO_KM
3	258	SURFACE SNOWMELT HEAT FLUX W/M2
4	4	TEMPERATURE AFTER LARGE SCALE PRECIP
4	10	SPECIFIC HUMIDITY AFTER LS PRECIP
4	201	LARGE SCALE RAIN AMOUNT KG/M2/TS
4	202	LARGE SCALE SNOW AMOUNT KG/M2/TS
4	203	LARGE SCALE RAINFALL RATE KG/M2/S
4	204	LARGE SCALE SNOWFALL RATE KG/M2/S
4	205	CLOUD LIQUID WATER AFTER LS PRECIP

Stash	Code	Field
4	206	CLOUD ICE CONTENT AFTER LS PRECIP
4	207	RELATIVE HUMIDITY AFTER LS PRECIP
4	208	VISIBILITY AFTER LS PREC IN LEVEL M
5	4	THETA AFTER CONVECTION INCREMENT
5	10	SPECIFIC HUMIDITY AFTER CONVECTION
5	13	CONV CLOUD AMOUNT AFTER CONVECTION
5	201	CONVECTIVE RAIN AMOUNT KG/M2/TS
5	202	CONVECTIVE SNOW AMOUNT KG/M2/TS
5	203	THETA INCREMENT FROM CONVECTION
5	204	SPECIFIC HUMID INCRMNT FROM CONVECTN
5	205	CONVECTIVE RAINFALL RATE KG/M2/S
5	206	CONVECTIVE SNOWFALL RATE KG/M2/S
5	207	PRESSURE AT CONVECTIVE CLOUD BASE
5	208	PRESSURE AT CONVECTIVE CLOUD TOP
5	209	TEMPERATURE AFTER CONVECTION
5	210	ICAO HT OF CONVECTIVE CLOUD BASE
5	211	ICAO HT OF CONVECTIVE CLOUD TOP
5	212	CONV. CLOUD AMOUNT ON EACH MODEL LEV
5	213	CONV CLOUD CONDENSED WATER KG/KG
5	214	TOTAL RAINFALL RATE: LS+CONV KG/M2/S
5	215	TOTAL SNOWFALL RATE: LS+CONV KG/M2/S
5	216	TOTAL PRECIPITATION RATE KG/M2/S
5	217	DILUTE CONVECTIVELY AVAIL POT E J/KG
5	218	LOWEST CONV CLOUD BASE LEVEL NO.
5	219	LOWEST CONV CLOUD TOP LEVEL NO.
5	220	LOWEST CONV CLOUD AMOUNT AFTER CONV
5	221	LOWEST CONV CLOUD LIQUID WATER PATH
5	222	PRESSURE AT LOWEST CONV CLOUD BASE
5	223	PRESSURE AT LOWEST CONV CLOUD TOP
5	224	ICAO HT OF LOWEST CONV CLOUD BASE
5	225	ICAO HT OF LOWEST CONV CLOUD TOP
5	226	TOTAL PRECIPITATION AMOUNT KG/M2/TS
6	2	U COMPNT OF WIND AFTER G.WAVE DRAG
6	3	V COMPNT OF WIND AFTER G.WAVE DRAG
6	201	U COMPONENT OF GRAVITY WAVE STRESS
6	202	V COMPONENT OF GRAVITY WAVE STRESS
6	203	STANDARD DEVIATION OF OROGRAPHY
6	204	OROGRAPHIC GRADIENT XX COMPONENT
6	205	OROGRAPHIC GRADIENT XY COMPONENT
6	206	OROGRAPHIC GRADIENT YY COMPONENT
6	207	U-ACCEL FROM SATURATED STRESS
6	208	V-ACCEL FROM SATURATED STRESS
6	209	U-ACCEL FROM HYDRAULIC JUMP
6	210	V-ACCEL FROM HYDRAULIC JUMP

Stash	Code	Field
6	211	U-ACCEL FROM TRAPPED LEE WAVES
6	212	V-ACCEL FROM TRAPPED LEE WAVES
6	213	VERTICAL TRANSMISSION COEFFICIENT
7	2	U COMPNT OF WIND AFTER VERT DIF'SION
7	3	V COMPNT OF WIND AFTER VERT DIF'SION
7	201	VERT FLUX OF U MOMENTUM FROM V.DIFFN
7	202	VERT FLUX OF V MOMENTUM FROM V.DIFFN
8	23	SNOW MASS AFTER HYDROLOGY KG/M2
8	24	SURFACE TEMPERATURE,AFTER HYDROLOGY
8	201	LAND SNOW MELT AMOUNT KG/M2/TS
8	202	LAND SNOW MELT HEAT FLUX W/M2
8	203	CANOPY THROUGHFALL AMOUNT KG/M2/TS
8	204	SURFACE RUNOFF AMOUNT KG/M2/TS
8	205	SUB-SURFACE RUNOFF AMOUNT KG/M2/TS
8	206	SOIL HYDROLOGY PARAMETER "BS"
8	207	VEG MODIFIED INFILTRATION RATE
8	208	SOIL MOISTURE CONTENT
8	209	CANOPY WATER CONTENT
8	210	VOL SMC AT WILTING
8	211	VOL SMC AT CRIT PT
8	212	VOL SMC AT FLD CAP
8	213	VOL SMC AT SATURATION
8	214	SATURATED SOIL CONDUCTIVITY
8	215	EAGLESON'S EXPONENT
8	216	THERMAL CAPACITY
8	217	THERMAL CONDUCTIVITY
8	218	VEGETATION FRACTION
8	219	ROOT DEPTH
8	220	SURFACE RESISTANCE TO EVAPORATION
8	221	SURFACE CAPACITY
8	222	INFILTRATION FACTOR
8	223	SOIL MOISTURE CONTENT IN A LAYER
8	224	SATURATED SOIL WATER SUCTION
8	225	DEEP SOIL TEMP. AFTER HYDROLOGY DEGK
8	226	DEEP SNOWMELT HEAT FLUX W/M2
9	4	TEMPERATURE AFTER DYNAMIC CLOUD
9	10	SPEC. HUMIDITY AFTER DYNAMIC CLOUD
9	201	LAYER CLOUD AMOUNT IN EACH LAYER
9	202	VERY LOW CLOUD AMOUNT
9	203	LOW CLOUD AMOUNT
9	204	MEDIUM CLOUD AMOUNT
9	205	HIGH CLOUD AMOUNT
9	206	CLOUD LIQUID WATER AFTER DYN CLOUD
9	207	CLOUD ICE CONTENT AFTER DYNAM CLOUD

Stash	Code	Field
9	208	CLOUD BASE FOR COVER.GT.0.1 OCTA KFT
9	209	CLOUD BASE FOR COVER.GT.1.5 OCTA KFT
9	210	CLOUD BASE FOR COVER.GT.2.5 OCTA KFT
9	211	CLOUD BASE FOR COVER.GT.3.5 OCTA KFT
9	212	CLOUD BASE FOR COVER.GT.4.5 OCTA KFT
9	213	CLOUD BASE FOR COVER.GT.5.5 OCTA KFT
9	214	CLOUD BASE FOR COVER.GT.6.5 OCTA KFT
9	215	CLOUD BASE FOR COVER.GT.7.9 OCTA KFT
9	216	TOTAL CLOUD AMOUNT - RANDOM OVERLAP
9	217	TOTAL CLOUD AMOUNT MAX/RANDOM OVERLP
9	218	CLOUD FRACTION BELOW FT ASL
9	219	LOW CLOUD BASE (FT ASL)
9	220	LOW CLOUD TOP (FT ASL)
9	221	WET BULB FREEZING LEV HEIGHT (M)
9	222	WET BULB TEMPERATURE (K)
9	223	TOTAL CLOUD TOP HEIGHT (KFT)
10	1	PSTAR AFTER ADJUSTMENT
10	2	U COMPNT OF WIND AFTER ADJUSTMENT
10	3	V COMPNT OF WIND AFTER ADJUSTMENT
10	4	THETA AFTER ADJUSTMENT
10	10	SPEC HUMID TOT WATER CONTENT:ADJUST
10	201	MEAN U OVER ADJ*LAYER THICK=MASS FLX
10	202	MEAN V OVER ADJ*LAYER THICK=MASS FLX
10	203	PSEUDO-RADIUS AT MODEL LEVELS
10	204	ETADOT FROM THE ADJUSTMENT STEP
10	205	RATE OF CHANGE OF PSTAR
10	206	GEOPOTENTIAL
10	207	MEAN U OVER ADJ * LAYER THICK * TEMP
10	208	MEAN V OVER ADJ * LAYER THICK * TEMP
10	209	MEAN U OVER ADJ * LAYER THICK *HUMID
10	210	MEAN V OVER ADJ * LAYER THICK *HUMID
10	211	MEAN U ADJ *LAYER THICK* LIQ WATER T
10	212	MEAN V ADJ *LAYER THICK* LIQ WATER T
10	213	MEAN U ADJ *LAYER THICK* TOTAL WATER
10	214	MEAN V ADJ *LAYER THICK* TOTAL WATER
10	215	MEAN U ADJ * LAYER THICK * U
10	216	MEAN V ADJ * LAYER THICK * U
10	217	MEAN U ADJ * LAYER THICK * V
10	218	MEAN V ADJ * LAYER THICK * V
10	219	MEAN U * LAYER THICK * GEOPOTENTIAL
10	220	MEAN V * LAYER THICK * GEOPOTENTIAL
10	221	MN U *LYR THICK* MOIST STATIC ENERGY
10	222	MN V *LYR THICK* MOIST STATIC ENERGY
10	223	ANGULAR MOMENTUM M1 KG M2/S X10-24

Stash	Code	Field
10	224	ANGULAR MOMENTUM M2 KG M2/S X10-24
10	225	ANGULAR MOMENTUM M3 KG M2/S X10-24
10	226	ANGULAR MOMENTUM W1 KG M2/S X10-24
10	227	ANGULAR MOMENTUM W2 KG M2/S X10-24
10	228	ANGULAR MOMENTUM W3 KG M2/S X10-24
10	229	CLOUD LIQUID WATER BEFORE DYNAMICS
10	230	CLOUD ICE CONTENT BEFORE DYNAMICS
12	2	U AFTER PRIMARY FIELD ADVECTION
12	3	V AFTER PRIMARY FIELD ADVECTION
12	4	THETAL AFTER PRIMARY FIELD ADVECTION
12	10	QT AFTER PRIMARY FIELD ADVECTION
12	201	OMEGA ON MODEL LEVELS
12	202	OMEGA ON PRESSURE LEVELS
13	2	U AFTER FILTERING AND DIFFUSION
13	3	V AFTER FILTERING AND DIFFUSION
13	4	THETAL AFTER FILTERING AND DIFFUSION
13	10	QT AFTER FILTERING AND DIFFUSION
13	201	QT SOURCE/SINK IN QT_POS KG/M2/S
14	201	ATMOS ENERGY CORR'N IN COLUMN W/M2
15	201	U COMPNT OF WIND ON PRESSURE LEVELS
15	202	V COMPNT OF WIND ON PRESSURE LEVELS
15	203	MAX CAT PROBABILITY. NEED MAX WIND
15	204	MAX CAT PROB LEVEL. NEED MAX WIND
15	205	CAT PROB @ P LEVELS. NEED MAX WIND
15	206	HEIGHT OF MAX WIND LEVEL- NOT AVALBL
15	207	ICAO HT OF MAX WIND LEV-NEED MAX U&V
15	208	PRESSURE OF MAX WIND LEV-NEED MAX U,
15	209	U COMPONENT OF MAX WIND-NEED MAX V&P
15	210	V COMPONENT OF MAX WIND-NEED MAX U&P
15	211	CAT PROB AVE 300 250 200MB NEED MAX
15	212	50 METRE WIND U-COMPONENT
15	213	50 METRE WIND V-COMPONENT
15	214	ERTEL POTENTIAL VORTICITY(THETA LEV)
15	215	UV ON PRESSURE LEVS.
15	216	T ON PRESSURE LEVS U GRID.
15	217	UT ON PRESS LEVS U GRID.
15	218	VT ON PRESS LEVS U GRID.
15	219	T**2 ON PRESS LEVS U GRID.
15	220	U**2 ON PRESS LEVS U GRID.
15	221	V**2 ON PRESS LEVS U GRID.
15	222	OMEGA ON PRESS LEVS U GRID.
15	223	OMEGA*T ON P LEVS U GRID.
15	224	OMEGA*U ON P LEVS U GRID.
15	225	OMEGA*V ON P LEVS U GRID.

Stash	Code	Field
15	226	SPECIF HUM;P LEVS;U GRID.
15	227	Q*U ON PRESS LEVS U GRID.
15	228	Q*V ON PRESS LEVS U GRID.
15	229	POTENTIAL VORTICITY ON PRESSURE LEVS
15	230	THETA ON POT VORT LEVS
15	231	TEST FIELD ON UV GRID-SINGLE LEVEL
15	232	TEST FIELD ON TH GRID-SINGLE LEVEL
15	233	TEST FIELD ON TH GRID-PRESS LEVELS
15	234	TEST FIELD ON TH GRID-MODEL LEVELS
16	201	GEOPOTENTIAL HEIGHT:LAYER BOUNDARIES
16	202	GEOPOTENTIAL HEIGHT: PRESSURE LEVELS
16	203	TEMPERATURE ON PRESSURE LEVELS
16	204	RELATIVE HUMIDITY ON PRESSURE LEVELS
16	205	WET BULB POTENTIAL TEMPERATURE
16	206	SURFACE SNOW PROBABILITY
16	207	ICAO HT OF -20 DEG ISO- NEED P,HT
16	208	PRESSURE OF -20 DEG ISO- NEED HT
16	209	ICAO HT OF FREEZING LEV- NEED P,HT
16	210	HEIGHT OF FREEZING LEV- NEED PRESS
16	211	PRESSURE OF FREEZING LEV- NEED HT
16	212	HT OF CONTRAIL LOWER LIM- NEED UPPER
16	213	HT OF CONTRAIL UPPER LIM- NEED LOWER
16	214	PRESSURE AT TROP LEV- NEED HT,TEMP
16	215	TEMP AT TROP LEVEL- NEED HT,PRESS
16	216	HEIGHT OF TROP- NEED TEMP, PRESS
16	217	ICAO HT OF TROP- NEED HT,TEMP,PRESS
16	218	HEIGHT OF -20 DEG ISO- NEED PRESSURE
16	219	THERMAL ADVECTION ON PRESSURE LEVELS
16	220	RADIO DUCT HEIGHT- NEED INTENSITY
16	221	RADIO DUCT INTENSITY- NEED HEIGHT
16	222	PRESSURE AT MEAN SEA LEVEL
16	223	THERMAL ADVECT AVE OVER 850 700 500
16	224	HEIGHT**2 ON PRESS LEVS.
16	225	GEOPOTENTIAL HT OF MODEL LEVEL

D JPLOT - IDL X-BASED GRAPHICS FOR UM DATA

D.1 Introduction

JPLOT is a fully interactive X-Windows widget based IDL graphical display program, designed to run on IEEE Unix systems. At present it is capable of reading 8 different dataset formats, these being:

1. New Mesoscale model dumps. (Code Author: Golding et. al. (UK Met. Office))
2. NH3D (Orographic flow) customised dumps. (Code Author: Miranda (Met. Dept. Reading))
3. Unified Model file extracts and PP-format files. (Code Author: UK Met. Office)
4. Large Eddy Model (LEM) customised dumps. (Code Author: UK Met. Office)
5. User written dump formats.
6. Simple pre-specified dump formats.
7. Baroclinic Wave Model dumps. (Code Author: Rotunno (NCAR))
8. 3D Semi-Geostrophic customised Dumps (Code Author: Met. Dept. Reading)

However in this document we only consider use of JPLOT with Unified Model (UM) data as this is the most applicable to the UWERN collaboration. For details about the other datasets usable with JPLOT please contact Ed Dicks at Reading.

JPLOT can read in two types of file containing UM data. The program interrogates the input file to deduce which type of file is supplied. The two file types are:

1. PP-format files; this is the most common type of UM data file. However there is a restriction when reading these files directly, this being that there must be no more than 120 multi-level fields in the file. If this restriction does not hold then the second type of file must be used. There is no restriction on the number of single level fields present in the PP-format input file. NB Smaller PP-format files may be generated using the utility EXFIELD (see Appendix F).
2. UM data extraction; this file contains a user specified subset of a PP-format file or Fieldsfile type file, and is created by running a pre-processing job (with script exfield, described in Section 9.2) on the PP-format or Fieldsfile file. This option is useful when the UM datasets are very large.

The data can be displayed in JPLOT a number of ways:

- Any arbitrary 2D orthogonal section through a 3D field
- Oblique vertical sections, from one grid point to another
- Any arbitrary orthogonal column or row of points producing an x-y line plot.
- Velocity vector plots (which may be overplotted) assuming U and V winds are present.
- 3D Iso-surface plots.

The user can then display the 2D sections in a number of ways, for example using images, contours or surface plots. Also various tool are available such as zoom utilities and other data field manipulation widgets. UM data may be displayed either on a rectangle corresponding to the equatorial grid (which the limited area models are run on) or with a standard cylindrical map projection. An overplotting facility also exists for plotting one field over another. The user can interactively alter various display parameters such as contouring parameters (values, linestyles, labeling, etc.) and axis values and titles etc. Hardcopy of graphical output can be obtained with a Postscript creation facility, which will be described later on.

A useful feature of JPLOT is that it has an option to call IDL procedures supplied by the user, so that JPLOT variables and displays may be manipulated in a more user specific way. The user supplies the names of these procedures during execution of JPLOT (described later). Later sections also describe some supplied user procedures and some stand alone procedures that may be used with UM data. The method of producing UM data animation sequences is described in Appendix D.10.

D.2 Example Output From JPLOT

In this section we show some example graphical output from JPLOT, the data shown was generated from running the UM in UK Mesoscale mode with resolution approximately 16.8 Km and a 92 X 92 X 31 grid. The particular cases shown are forecast data at 06Z with the model run starting at 00Z on 17/5/95. Figure 11 shows a horizontal section of Potential Vorticity (PV) at a pressure level of 700 mBar

Figure 12 shows the PMSL field contoured with a contour interval of 1mb with wind vectors at a level of 1000 mb overplotted. The projection used is the equatorial grid used in the model, displayed on a square region (reflecting the square 92 X 92 array of data values). The wind vectors are displayed at a frequency of every 3 grid cells, using JPLOT's velocity vector customisation options.

D.3 Setting Up JPLOT

The JPLOT source code is supplied in a tar file called jplot.tar. Move the tar file to a directory where you want the source code to reside, then issue the command:

tar xvf jplot.tar

To ease explanation we will define an environmental variable called JPLOT_SOURCE and set it to point to the location of the JPLOT source, i.e. the directory where the tar file was unpacked.

To run the IDL program JPLOT, IDL needs to know where to find the JPLOT source code, this is accomplished by appropriate modification of the environmental variable IDL_PATH. Then do one of the following:

1. Korn-Shell users modify your .kshrc file by adding the following line at the end of the file;

   addpath +"$JPLOT_SOURCE" IDL_PATH prepend

2. C-Shell users modify your .login file by adding the following line at the end of the file;

   setenv IDL_PATH +"$JPLOT_SOURCE":"$IDL_PATH"

The effect of these steps is to force IDL to search the directory $JPLOT_SOURCE first for programs, then followed by your current directory and then the main IDL library directories.

A file called jplot_setup.pro is supplied in the JPLOT distribution, and is used to define the names of the available Postscript printers on your system and to define the location of various sections of certain JPLOT code. On editing the file jplot_setup.pro you can see that the printer names are defined by filling in the entries of the array printers. There is also the idl string variable jplot_source that needs to be set to indicate the location of the main JPLOT directory, i.e. the directory in which the tar file was unpacked. For example if jplot.tar was untarred in directory /usr/local/jplot then set jplot_source=/usr/local/jplot.

Some of the idl code calls some "shared object libraries" which are compiled pieces of fortran and C code which have been written to speed up certain intensive computations. These shared object libraries will need compiling on your system, a shell script called build_sols has been supplied to perform this function. The script needs 1 argument to indicate which type of dataset you are working with, for example to build the shared object libraries needed for use with UM data, type

sh build_sols um

in directory $JPLOT_SOURCE. The arguments that would be needed for other dataset types are listed in the README file. If you are planning to use JPLOT with more than 1 dataset then simply repeat the command build_sols with the other dataset name indicator as given in README.

D.4 Running JPLOT

Firstly, to execute IDL simply type 'idl' at the Unix prompt, a prompt 'IDL>' should then appear. It is possible that all the available licences to use IDL are in use, if this is the case, a message to this effect will appear, it is not possible to run JPLOT and you will have to try again later.

To run JPLOT, type '.run jplot' at the IDL prompt, this compiles and executes the program. A number of widget menus then appear prompting the user to supply information such as the dump format to be read in and the type of display etc.

When the widget menu's have all been supplied with your selections, the main display widget is brought up onto the screen. This contains a main display window for visualising the data, a colour scale window, a column of buttons and a row of pull-down-menu's to alter the display and for the interactive supply of various display/output parameters. Two sets of widget labels are also present under the display windows, the set on the left indicate the data file name, display section, field, index etc. The set on the right are for messages such as instructions to the user, errors, information, and the status of the program, i.e. whether it is ready for the next command. The program status indicator is important; only when it displays 'READY' will JPLOT respond to user requests, otherwise it gives the user information as to what it is doing.

If, at this stage, the program has executed properly no IDL prompt should be visible in the window the program was executed from. However, sometimes due to a quirk of IDL, execution terminates and the IDL prompt reappears so that further use of the program is not possible. To remedy this type the following 2 commands at the idl prompt:

1. 'retall', then hit return, followed by
2. 'xmanager', hit return

The program should now be ready for use, and no IDL prompt should be visible. This method of recovery is also useful to restart execution after an abortive error causes a return to the IDL prompt. The IDL command .go is also useful for restarting execution of a program which has already been compiled with the .run command (in the same idl session).

There is also an on-line help system available by clicking on the 'Help' button in the right column of buttons. The program is still undergoing development and has not been fully tested, therefore it is likely that some bugs exist. If you find a bug, basically a command which causes the program to abort, indicated by error messages in the workstation window, followed by return of the IDL prompt, please report them to Ed Dicks at Reading, including a copy of the error message.

D.5 Hardcopy of Output

When the user requests hardcopy creation, the contents of the display window are written to the output graphics file, the type of which depends on your choice. Basically, what you see in the display window, you will have in your output graphics file. The hardcopy options may be altered on the 'Hardcopy Options' widget which is launched by clicking on the relevant option on the 'Hardcopy' pull-down-menu in the top row of menu's. The procedure for creating hardcopy is as follows:

1. Select the orientation of the output (default - landscape).
2. Select the colour type of the output (default - b/w).
3. You may change the 'root' filename of the output file, the default is 'idl'.
4. Create the graphics file of the required form, i.e. Postscript etc.

5. Postscript and encapsulated postscript output may be previewed using Ghostview if required.

6. Send the output file to a printer of your choice, the default is the first entry of the printers array, which is set up in the file jplot_setup.pro.

Once the graphics file has been sent to the printer you are asked whether you want to delete the file, click 'YES' or 'NO' on the menu at the bottom of the rightmost column.

D.6 Calling your own IDL procedures from JPLOT

The option exists of calling up to 20 of your own IDL procedures from within the IDL JPLOT program. This is enabled by taking the 'Call User Supplied Procedure' option from the 'Miscellaneous' pull down menu. You are then asked to supply the name of your procedure (without the .pro extension) in the supply window. N.B. the name of the procedure must be the same as the root filename of the file it is contained in, i.e. if you call your procedure myproc then it must be in a file called myproc.pro. The procedure is 'forceably compiled' so that the latest version of the procedure is always executed.

The JPLOT program has been set up to call the user supplied procedure straight away, however it is also designed to call the procedure during the creation of graphical output files, as it seems very likely that users might wish to fine tune their graphical output. The users can control the position their procedures are called at so that they may be called instantly, during graphical hardcopy creation, during the JPLOT display 'UPDATE' step, or any combination of these. This is accomplished by programming a test in the supplied procedure on the JPLOT variable 'uproc_setting' which takes the form of a case statement, an example of which is shown below. The variable uproc_setting has a value associated with it which defines the location the program is currently executing at. For example if uproc_setting=2 then the program is currently updating the X-Windows display. If you do not want your procedure to be executed during this step, then simply program a 'return' statement in the case that uproc_setting=2. In the example below the user procedure would only be executed instantly and just after the end of graphical output creation.

An example procedure myproc is shown below, JPLOT variables can be accessed by including the JPLOT common block file jplot_comm as in the example, in fact the common block file must always be included. Also shown in the example below is the method of supplying text, integers and floating point numbers to your procedure during execution using the data supply widget window. Also shown is the method of using the 'Click Yes or No' widget for supplying a 'Yes' or 'No' response. (N.B. a semi-colon in IDL indicates a commented line and may appear anywhere along a line.)

```
PRO myproc
@jplot_comm ; insert common blocks
;
; case statement below controls where the procedure is executed
;
case uproc_setting of
1:              ; straight away
2: return       ; during UPDATE step
3: return       ; just before start of graphics creation
4:              ; just after end of graphics creation
endcase
;
; prompt for supply of text
print,'Enter your text now in the supply window'
your_default='default text' ; example default text
supply_value_event, your_default
; the supply widget returns the variable "svalue"
your_text=svalue
```

```
;
; prompt for supply of an integer
print,'Enter your integer now in the supply window'
your_default=1 ; example default integer
supply_value_event, your_default
your_int=fix(svalue)
;
; prompt for supply of a floating point number
print,'Enter your floating point number now in the supply window'
your_default=0.0 ; example default float
supply_value_event, your_default
your_float=float(svalue)
;
; prompt for a Yes or No response
print,'Click Yes or No'
supply_answer_event
; the answer widget returns the variable "answer"
if answer eq 0 then response='No Clicked'
if answer eq 1 then response='Yes Clicked'
;
end
```

D.7 JPLOT Features with UM Data

The following features are available with UM data from JPLOT, and are all set using the "Change Display" pull down menu:

- Horizontal sections of UM data are plotted by default on a rectangle corresponding to the Equatorial grid that the "limited area models" are run on. With this projection it is possible to overplot labelled lines of latitude and longitude, and also plot a coastline which is obtained from the Land-Sea Mask file, which is supplied with JPLOT. The land sea mask file contains an array of integer data the same size as the UM horizontal grid, and conatins a 1 where the grid point corresponds to land and a 0 otherwise. JPLOT plots a coastline using this file by drawing a contour through the value of 0.5 for the mask data which produces a good approximation to the coastline. Horizontal sub-sections using this projection are also possible.

- Alternatively, horizontal sections may be plotted using idl's cylindrical map projection, which plots a high resolution coastline and automatically interpolates contours onto the map. The user may alter the size of the map, the data being automatically clipped to fit the map extent.

- Network Radar Data may be overplotted on the current display, whether the display is using the standard projection or the cylindrical map projection, the procedure for overplotting Radar data knows which projection is in effect and acts accordingly. Alternatively, you may remove the UM data from the current display (for example by specifying 1 contour value outside the displayed data range) so that only Radar data appears on the display. Also a stand alone procedure exists for plotting Radar data, but this only plots on a cylindrical map projection, this procedure is described in the next section.

- Satellite data (UKMO EC region only at present) may be plotted with UM fields overlaid. The method of plotting is as follows; a small square of the required intensity is plotted at the lat/lon coordinate of each Satellite data point, and can only be done with a map projection. Hence the user may alter the map projection limits to select an arbitrary portion of the Satellite data region. A more sophisticated approach for plotting the Satellite data is being developed for

publication quality output. A stand alone procedure also exists to plot the Satellite data on its source projection which is the polar stereographic projection, this is described in the next section.

- JPLOT has an integrated Tephigram creation facility to plot tephigrams based on UM data, either data defined on model or pressure levels. The procedure interrogates the JPLOT dataset to find the most suitable set of data to plot the tephigram, if any. There is also an option to plot Windbarbs on the tephigram. The tephigram procedure may also be used as a stand alone procedure to plot tephigrams from non UM data sources, see the next section.
- JPLOT has a vertical coordinate conversion facility which presently may perform the following vertical interpolation of 3D UM fields:

  1. Fields on Model levels converted to Pressure levels.
  2. Fields on Model levels converted to Theta levels.
  3. Fields on Pressure levels converted to Theta levels.

  In each case the user may specify the vertical resolution of the interpolated fields.

- Wind Wectors may be plotted on their own or overplotted on UM data, with U-V, U-W and V-W wind vectors possible. Also, extensive wind vector customisation options are available. The wind vectors may be plotted on the following surfaces, pressure (the default), theta, 10 metre level and 50 metre levels, but only U-V vectors are possible on the 10 and 50 metre levels. Winds on pressure, 10 and 50 metre levels are available as diagnostics from the UM but U and V on theta levels must be calculated using the vertical coordinate conversion facility described above.
- Animation sequences, of horizontal sections only, may be performed from within JPLOT or outside, and is described in detail in Section D.10.

D.8 JPLOT Additions and Stand Alone Procedures

A number of idl procedures have been written to be run as stand alone programs independently of JPLOT, these are:

- plot_radar - This procedure plots the contents of a Network Radar data file on a standard cylindrical map projection, giving a rainfall rate map in $mmhr^{-1}$ over the UK. An option exists for selecting sub-regions of the UK and producing Postscript output.
- plot_sat_data - This procedure plots an EC region Satellite image (1 image per file) including a high resolution coastline and lines of latitude and longitude. The Satellite image is in Polar Stereographic projection, hence the resulting Satellite plot uses idl's Polar Stereographic projection facility.
- tephi - Plots a tephigram, reading input data from an ASCII file with a number of different input formats and specifications available. N.B. JPLOT also has an integrated Tephigram creation facility via a widget interface which utilises this procedure tephi.pro (and also the user procedure write_tephi_data.pro described below).

The following idl procedures have been written as "user procedures" to be called from within JPLOT, there are usually a few options and switches in the top of these files which need editing to suit your application. It is planned that some of these procedures will be available via menu's from JPLOT in the future.

- extract_column - Extracts a vertical column of data from a 3D field at a given lat/lon coordinate.
- ll2gbn - Prints the nearest grid block number given the lat/lon coordinate.

- grid_dots - Plots a dot at every grid point for the UK Mesoscale model grid.
- plot_multi - Plots either 4 (2 X 2) or 8 (2 X 4) fields on a page, output is directed to a Postscript file only.
- plot_mlevs - Plots the pressure values of a given section of model levels at a given time (Postscript output only).
- plot_rad - Overplots on the current display the contents of a Network Radar data file. The base plot may be the standard UM projection or a cylindrical map projection. This functionality is also available from an option in the change display menu.
- plot_sat - Plots an EC region Satellite image on the current display, which must be a map projection, then overplots the current UM field on the Satellite image.
- plot_sf - Overplots on the current display the contents of a UKMO Sferics file(s), N.B only applicable with Map Projections.
- rad2meso - Interpolates Network Radar data onto the UK Mesoscale grid to facilitate comparison of radar data with model precipitation fields.
- write_tephi_data - Writes out a data file suitable for loading into the stand alone procedure tephi.pro described above for producing a tephigram. N.B This procedure is also used by JPLOT's automated Tephigram creation facility.

D.9 Merging UM data for JPLOT

It is possible that data items required for a JPLOT session are contained in more than 1 input file, however only 1 input data file may be loaded into JPLOT at a time. It is therefore necessary to merge the required input files into a single file, the method of doing this depending on the type of file.

1. PP-format - These files may simply be concatenated using the Unix utility cat on any Unix system. An unlimited number of these files may be concatenated, however the JPLOT restriction on the number of multi-level fields present must hold if they are required for use with JPLOT.
2. Extracted Data - Data extracted from PP-format and Fieldsfile files using exfield may be concatenated using a program called umd_merge, but this must be done on a Sun, HP or SGI Unix system. A maximum of 20 extracted data files may be merged into 1 file. To compile this utility from the source code umd_merge.c type:

   cc -O2 -o umd_merge umd_merge.c

   N.B. The gnu C compiler gcc may also be used.
3. Fieldsfile - These data files cannot be merged directly. If data from more than 1 of these files is required for merging then either they must be converted to PP-format then concatenated as in (1) or the required data extracted using exfield which then should be merged as in (2).

D.10 Animation Sequences in JPLOT

D.10.1 The Animation Procedure

Animation sequences may be viewed in JPLOT using a utility called ividi supplied in the JPLOT distribution. The ividi program reads in a very specific data file which first must be created by running a pre-processing program on a UM data extraction file, i.e. a file produced by running exfield in animation sequence mode.

The pre-processing program produces a binary data file suitable for use with the idl animation widget cw_animate, and consists of a series of 2D byte arrays ('animation frames'). The byte values

are scaled between 0 and 255 so that the minimum data value over all the frames corresponds to a byte value of 0 and the maximum data value a byte value of 255. A pre-processor option also exists to specify the maximum output byte value, which should be used if a discrete colour scale is required. A global minimum and maximum data value may either be calculated by the pre-processing program or supplied by the user. The user may specify the dimensions of the animation frames in pixels, the data being converted to these specified dimensions by bi-linear interpolation. There is no limit to the number of animation frames that may be specified.

For details of how to animate data from the other sources of model data that are used with JPLOT, contact Ed Dicks at Reading who can supply another more general document on animation with JPLOT.

D.10.2 The Animation Pre-Processor

The UM animation pre-processor is called umanim and must be run on an IEEE Unix system. The source code is in umanim.c, to compile it use the command:

```
cc -O2 -o umanim umanim.c
```

N.B. The Gnu C compiler gcc may also be used.

The pre-processor input data file must have a very specific contents, i.e. only 1 field type at a particular level index but at many times, and must at present be a 'UM data extraction' rather than a PP-formt file. See the section on the UM data extraction program exfield which describes how to extract UM data suitable for animations. The exfield program only works in terms of horizontal sections (due to the structure of UM data files) and so animations of vertical sections is not currently possible. The output of umanim is written to a file called um_anim.dat, if the file already exists then it will be overwritten.

The pre-processing program was written in C and hence can utilise an argument list which is as follows:

```
umanim file xsize ysize plot_coast ncolours calc_lims [mindata] [maxdata] [mask_image]
```

The parameters in the argument lists have the following meanings (the bracketed parameters above should only be supplied if calc_lims and/or plot_coast are set accordingly):

1. file - The filename of the UM data extract for input.
2. xsize - The required X-dimension of the output animation frames, in pixels.
3. ysize - The required Y-dimension of the output animation frames, in pixels.
4. ncolours - Set this parameter to an integer specifying the number of discrete colour bands to use for the animation image. Set to 256 to use the full range of the colour table that will be used in the idl session. N.B. To see the effect of using the discrete colour scale then set a discrete colour table in JPLOT using the colour table widget launched from the Miscellaneous pull down menu.
5. calc_lims - Set to 1 to specify that the pre-processing programme should calculate the global minimum and maximum of the field data values. Otherwise set to 0 and supply the further 2 arguments mindata and maxdata described below.
6. mindata - should only be supplied if calc_lims=0 and represents the required global minimum of the field data, and is used to scale the resulting animation image byte values.
7. maxdata - should only be supplied if calc_lims=0.

8. plot_coast - Set this to 1 to enable the plotting of a coastline on the animation images, (i.e. should only be used with horizontal sections). If plot_coast=1 then a file (which should pre-exist) is read in with name specified by the very last command line parameter, and which should contain a byte valued Land Sea mask at the same resolution as the required output animation frames, i.e. xsize by ysize. The coastline points are plotted as 'white pixels' on the animation frames. N.B. The relevant mask_image file can be supplied by Ed Dicks at Reading.

An example pre-processing operation on a UM data extraction file is shown below:

umanim extract.dat 480 320 1 256 1

The animation frames are horizontal sections of a given field at a particular level index, with the animation frame size being 480 by 320 pixels. The pre-processor has also been instructed to calculate the global minimum and maximum of the data values. The resulting output file is called 'um_anim.dat' and should have a size of 480 * 320 * NFIELDS bytes, where NFIELDS is the number of fields in file extract.dat.

D.10.3 Animations in idl

An animation sequence may be started in idl in one of two ways. Firstly at the idl prompt using the idl program ividi which resides in the anim directory of the JPLOT distribution, this program will automatically be accessed on issue of the ividi call. The calling sequence is described below:

IDL > ividi,'um_anim.dat',width=600,height=400

i.e. an animation sequence of frame size 600 by 400 pixels, i.e. created with the pre-processor arguments of xsize=600 and ysize=400.

Secondly an animation may be started up from within a JPLOT session, using the 'Animation Sequence' option on the 'Change Display' pull down menu. JPLOT will look for the animation file um_anim.dat in the current directory and if it does not exist will issue a Warning message to this effect and return. If the file does exist JPLOT will call ividi with this filename and with image dimensions (width and height arguments) identical to the size the image would take in the JPLOT main display window, i.e. the image displayed in JPLOT will be 480 by 320 pixels unless it is a horizontal section and NX is equal to NY (i.e. the number of grid blocks in the x and y directions are identical), in this case it will be 320 by 320.

NB These sizes will be different if you have customised the size of the JPLOT main plotting window.

If the animation file called in this way was not created with the appropriate image dimensions then the animation frames will not be read in properly resulting in an animation of garbage, however no errors will be reported.

The animation appears in a window of a self-contained animation widget, which has various controls. Tape recorder style controls are used for stopping and direction of playback, the speed of the animation may be controlled with a slider, and a new colour table may also be loaded.

Animations produced as just described do suffer from certain limitations, these being that the animation frames do not have any annotations or labelling, particularly time information, as they are produced from the raw field data. However, the time of an animation frame can be deduced from information supplied on the animation widget.

E MDIAG - A DIAGNOSTICS PROGRAMS SUITE

E.1 Structure

MDIAG is a collection of FORTRAN subroutines, each called individually by an overlay program called **mdiag_main.f** which also initialises a number of arrays and constants. There are presently 49 diagnostics available, but the user has the option of saving only those that are required - this is sensible because of the size of the files (see section E.3).

We plan to add more diagnostics in the near future - users' suggestions as to new diagnostics are very welcome, and we will try to incorporate them into the existing package.

All routines are now self-sufficient in that all the required parameters/arrays are passed to that routine as arguments, hence the routines can be incorporated into other programs. Each subroutine is called from the main overlay program, **mdiag_main.f** which has the following overall structure

- INCLUDE two resolution-dependent files,
  1. MDIAG.PARAMETERS which sets up array dimensions
  2. RESOLUTION_SPECIFIC.DATA which includes the pressure levels onto which the UM data will be interpolated and the coeffiecients required to do this interpolation.
- CALL GRID_SETUP, to set up the CORIOLIS force (as a function of real latitude), as well as the cos ϕ term required by the $\partial/\partial\lambda$ and $\partial/\partial\phi$ derivatives (in the rotated latitude-longitude frame)
- Loop over time,
  1. reading in the 6 basic fields g,T,u,v,q,w
  2. calculating the diagnostics by calls to the required subroutine
  3. Write out the required diagnostics in a pp-format file
  4. Repeat the time step until end of file

There are a number of checks to make sure that the we have all the correct input data, and that parameters are sensible.

NB There are actually two version of MDIAG available. One uses COMMON blocks and the other solely by self-contained calls to individual subroutines where all the necessary parameters are passed through the argument list. The COMMON block version runs some 5 times quicker than the latter version, but the executable is enormous (50Mb for the UK Meososcale model and 90Mb for the LAM). Both versions require you to have a Fortran compiler that allows the dynamic allocation of arrays.

E.2 Compiling and running MDIAG under UNIX

MDIAG runs under UNIX.

Note that the executable depends on the resolution of the data, so that a different executable must be generated for each of the LAM or UKMESO resolutions. This is because of the pressure interpolation coefficients which are specific to a given resolution. Source code, compile and run scripts are available to build executables. The procedures for producing an executable and running MDIAG are almost trivial, e.g

- To produce an executable that works for the LAM area type

  compile_mdiag -rLAM

  The compile_mdiag script sets up the necessary symbolic links to the aforementioned resolution-specific INCLUDE'd files and produces an executable.

- to run MDIAG for LAM data in a file called 950820_LAM.00Z.pp, type

run_mdiag -rLAM -i950820_LAM.00Z.pp

The output file will reside in the same directory and be called **950820_LAM.00Z.pp.mdiag**

E.3 Input and output data formats

PP-format: The input data is a pp-format file, a binary file with a fixed 64-word header, made up of 45 INTEGER*4 and 19 REAL*4 words, followed by the data, which is MX*MY REAL*4 words, where MX and MY are the number of grid points in the two directions (λ, ϕ) The pp-format files are very large, as they include data for an entire forecast run. In general, the size of pp-format file can be calculated as follows

$$BYTES = (MX \times MY \times TIMESTEPS + 64) \times 4 \times LEVELS \times VARIABLES \qquad (1)$$

For example,

- A pp-format input file for a typical LAM run to T+48 3-hourly (17 time-steps), with the 6 basic variables on model levels requires
  17x(229x132+64)x19x6x4 bytes, or about 235Mb of disk space
- A pp-format input file for a typical UK MESO run to T+18 hourly, with the 6 basic variables on model levels requires
  19x(92x92+64)x31x6x4 bytes, or over 120Mb of disk space
- A pp-format output file for LAM data at a SINGLE TIME STEP, computing all 76 available diagnostics on 10 pressure levels (1000mb-100mb) requires
  (229x132+64)x10x76x4 bytes, or about 59Mb of disk space per time step.
- A pp-format output file for UK MESO data at a SINGLE TIME STEP, computing all 49 available diagnostics on 19 pressure levels (1000mb-100mb) requires
  (92x92+64)x19x76x4 bytes, or about 32Mb of disk space per time step.

They are not small!!! Appendix B is a Met. Office document detailing the structure of the pp-header.

E.4 Diagnostics - a list of the subroutines

General vector operations and derivatives

divergence.f

Computes the horizontal divergence of a vector function

$$\nabla.\mathbf{f} \;=\; \frac{1}{a\cos\phi}\left(\frac{\partial f_\lambda}{\partial\lambda} + \frac{\partial(f_\phi\cos\phi)}{\partial\phi}\right) \qquad (2)$$

grad.f

The magnitude of the gradient of a scalar function f is defined as

$$|\,\nabla \mathrm{f}\,| = \sqrt{\left(\frac{1}{a\cos\phi}\frac{\partial f_\lambda}{\partial\lambda}\right)^2 + \left(\frac{1}{a}\frac{\partial f_\phi}{\partial\phi}\right)^2} \qquad (3)$$

and the direction is given by

$$\tan^{-1}\left[\frac{\left(\frac{\partial f}{\partial\phi}\right)}{\left(\frac{\partial f}{\partial\lambda}\right)}\right] \qquad (4)$$

dbydlam.f, dbydphi.f, dbydp.f

To compute the first derivatives wrt λ, ϕ and pressure p, namely

$$\partial/\partial\lambda, \partial/\partial\phi, \partial/\partial p,$$

3-point finite differences are used for the first derivatives. See e.g. Abramowitz and Stegun. The 3-point centre-, forward- and backward-difference formulae are

$$f'_0 = \frac{1}{2h}(-f_{-1} + f_1) \tag{5}$$

$$f'_0 = \frac{1}{2h}(-3f_{-1} + 4f_0 - f_1) \tag{6}$$

$$f'_0 = \frac{1}{2h}(f_{-1} - 4f_0 + 3f_{-1}) \tag{7}$$

curl.f Computes the $\hat{\mathrm{k}}$ component of a vector **f**, namely **k**.∇**xf**, or in component form

$$\mathbf{k}.\nabla\mathbf{xf} \equiv \frac{1}{a\cos\phi}\frac{\partial f_\phi}{\partial\lambda} - \frac{\partial(f_\lambda\cos\phi)}{\partial\phi} \tag{8}$$

gradsq.f

The horizontal component of ∇^2 is computed using a 5-point finite difference scheme. Centre-differences are used everywhere except at the upper boundary which uses backward differences and at the lower boundary which uses forward differences.

$$\nabla^2 f = \frac{1}{a^2\cos^2\phi}\frac{\partial^2 f}{\partial\lambda^2} + \frac{1}{a^2\cos\phi}\frac{\partial}{\partial\phi}\left(\cos\phi\frac{\partial f}{\partial\phi}\right) \tag{9}$$

The 5-point centre-weighted scheme is

$$\nabla^2 f_{\lambda_i,\phi_j} = \frac{1}{h^2}(-f_{-2,j} + 16f_{-1,j} - 30f_{0,j} + 16f_{1,j} - f_{2,j}) \tag{10}$$

advection.f

Computes the horizontal advection of a vector **f** w.r.t. a velocity vector **v**, namely

$$\mathbf{v}.\nabla\mathbf{f} \tag{11}$$

Thermodynamic variables

wet_bulb_potential_temperature.f

relative_humidities.f

potential_temperature.f Using the standard pressure $p_0 = 1000.0$mb and specific heat at constant pressure $c_p = 1005.0$ and gas constant for dry air $R = 287.05$, the potential temperature θ is given by

$$\theta = T\left(\frac{p_0}{p}\right)^{\frac{R}{c_p}} \tag{12}$$

humidity_mixing_ratio.f

From the GOFF-GRATCH formula, we define the constants,

$$\begin{aligned} A_1 &= 10.79574 \\ A_2 &= 5.028 \\ A_3 &= 1.50475 \times 10^{-4} \\ A_4 &= 0.4287 \times 10^{-3} \\ A_5 &= 0.78614 \\ E_1 &= -8.2969 \\ E_2 &= 4.76955 \\ T_0 &= 273.16 \end{aligned}$$

then, the saturation vapour pressure of water (e_s), in mb, is

$$log(e_s) = A_1\left(1 - \frac{T_0}{T}\right) - A_2 log\frac{T}{T_0} + A_3\left[1 - 10^{E_1\left(\frac{T_0}{T}-1\right)}\right] + A_4\left[10^{E_2\left(1-\frac{T}{T_0}\right)} - 1\right] + A_5 \qquad (13)$$

Using the ratio of the molecular weight of water vapour to air $\epsilon = 0.622$, the relative humidity RH(%) and pressure p (mb), the humidity mixing ratio (r) is given by

$$r = \epsilon\frac{RH}{100}\frac{(e_s)}{p} \qquad (14)$$

eq_potential_temperature.f

Computes the equivalent potential temperature θ_e and saturation equivalent potential temperature (at 100% humdity) θ_e, using the formula in Bolton D., 1980, *Month. Weather Review*, **108**, 1046. Using the humidity mixing ratio (r) previously calculated, and computing the water vapour pressure E and the lifting condensation level TL according to,

$$\begin{aligned} E &= \frac{1000\times r\times p}{622.0+1000\times r} \\ TL &= \frac{2840.0}{3.5logT - logE - 4.805} + 55.0 \quad E > 0 \\ TL &= 55 \quad E \leq 0 \end{aligned}$$

and further defining the potential temperature θ (different to that computed in potential_temperature.f), namely

$$\theta = T\left(\frac{1000}{p}\right)^{0.2854\left(1-0.28\times10^{-3}1000\times r\right)} \qquad (15)$$

then

$$\theta_e = \theta exp\left(\frac{3.376}{TL} - 0.00254\right)1000\times r\left(1 + 0.81\times10^{-3}1000\times r\right) \qquad (16)$$

The saturation equivalent potential temperature θ_e^{SAT} is at 100% humidity.

$$\theta_e^{sat} = \theta_e(100\%) \qquad (17)$$

density.f

From the definition of the virtual temperature θ_V

$$\theta_V = T\left(1 + 0.61\frac{r}{1+r}\right) \qquad (18)$$

where r is the humidity mixing ratio, and using the gas constant for dry air $R = 287.05$, the density ρ is given by

$$\rho = \frac{p}{R \times \theta_V} \tag{19}$$

GENERAL METEOROLOGICAL DIAGNOSTICS

geostrophic_winds.f

Geostrophic and ageostrophic winds. In vector form,

$$\mathbf{v_g} = -\frac{1}{f}\mathbf{k} \times \nabla\Phi \tag{20}$$

$$\mathbf{v_g} = -\frac{g}{f}\mathbf{k} \times \nabla Z \tag{21}$$

$$\mathbf{v_{ag}} = \mathbf{v} - \mathbf{v_g} \tag{22}$$

absolute_vorticity

Computes the absolute vorticity ζ given the relative vorticity $\xi = \mathrm{k}.\nabla \times \mathbf{v}$. In vector form,

$$\xi = \mathrm{k}.\nabla \times \mathbf{v} \tag{23}$$

$$\zeta = \xi + f \tag{24}$$

wind_magnitude_direction.f

The magnitude of the wind and direction α are given by

$$\sqrt{(u^2 + v^2)} \tag{25}$$

$$\alpha = \tan^{-1}\left(\frac{v}{u}\right) \tag{26}$$

potential_vorticity.f

Dry and moist potential vorticity are given by

$$DRYPV \equiv \frac{1}{\rho}\zeta.\nabla\theta \tag{27}$$

$$MOISTPV \equiv \frac{1}{\rho}\zeta.\nabla\theta_{\mathbf{w}} \tag{28}$$

$$\tag{29}$$

qvector.f

Q_1, Q_2 vectors and their divergence, $\nabla.\mathbf{Q}$

$$Q_1 = -\frac{R}{p}\frac{1}{a\cos\phi}\frac{\partial \mathbf{v_g}}{\partial\lambda}.\nabla T \tag{30}$$

$$Q_2 = \frac{R}{p}\frac{1}{a}\frac{\partial \mathbf{v_g}}{\partial\phi}.\nabla T \tag{31}$$

$$\nabla.(Q_1 + Q_2) = \frac{1}{a\cos\phi}\left(\frac{\partial Q_1}{\partial\lambda} + \frac{\partial\left(Q_2\cos\phi\right)}{\partial\phi}\right) \tag{32}$$

omega_eqn.f Computes 3-D Laplacian inversion of the omega equation including diabatic heating. This program calls **invlap3d.f** which uses NAG routines to do the 3-D Laplacian inversion.

The Ω-equation with diabatic heating is given by

$$\sigma^2\nabla^2\omega + f_0^2\frac{\partial^2\omega}{\partial p^2} = -2\nabla.Q - \frac{L}{c_p\rho T}\nabla^2\left(\frac{\omega\partial q}{\partial p}\right) \tag{33}$$

where L is the latent heat of vaporisation or sublimation,

$$\begin{aligned} L_v &= 2.5008\times10^6 - 2.3\times10^3 T \quad T>0 \\ L_s &= 2.839\times10^6 - 3.6(T+35)^2 \quad T\le 0 \end{aligned} \tag{34}$$

and c_p the specific heat capacity at constant pressure and q the saturation mixing ratio (computed using either **svp.f** or **svpice.f**, *viz.*

$$\begin{aligned} c_p &= 1004 \\ q &= \frac{e_s}{p} \end{aligned} \tag{35}$$

In addition, the following can be computed using the basic vector operations and derivative routines.

- Geostrophic relative vorticity ξ_g computed using

$$\xi_g = \mathrm{k}.\nabla\times\mathbf{v_g} \tag{36}$$

(37)

- Divergence of the wind field

$$\nabla.\mathbf{v} = \frac{1}{a\cos\phi}\left(\frac{\partial u}{\partial\lambda} + \frac{\partial(v\cos\phi)}{\partial\phi}\right) \tag{38}$$

- Vertical derivatives

$$\frac{\partial u}{\partial p} \tag{39}$$

$$\frac{\partial v}{\partial p} \tag{40}$$

$$\frac{\partial\theta}{\partial p} \tag{41}$$

$$\frac{\partial\theta_e}{\partial p} \tag{42}$$

FRONTAL ANALYSIS

geostr_defmn.f

Magnitude and components of the geostrophic deformation. The equations are derived from Keyser D., Reeder M.J., Reed R.J, 1988, *Month. Weather Review*, **116**, 762. The Deformation E (from eqs. 1.1-1.4) is given by

$$
\begin{aligned}
E &= \sqrt{E_{st}^2 + E_{sh}^2} \\
E_{st} &= \frac{1}{\cos\phi}\frac{\partial u_g}{\partial \lambda} - \frac{1}{a}\frac{\partial v_g}{\partial \phi} \\
E_{sh} &= \frac{1}{a\cos\phi}\frac{\partial v_g}{\partial \lambda} + \frac{1}{a}\frac{\partial u_g}{\partial \phi} \\
\beta &= \delta - \alpha \\
\tan 2\delta &= \frac{E_{sh}}{E_{st}} \\
\tan\alpha &= -\frac{\partial\theta}{\partial\lambda}\left(\cos\phi\frac{\partial\theta}{\partial\phi}\right)^{-1}
\end{aligned}
$$

local_grad.f

Computes local value (estimated value in the adjacent baroclinic zone, Hewson 1997, *Met. Apps.*, accepted) of $|\nabla\theta|, |\nabla\theta_w|$

$$|\nabla\theta| + \frac{a\,|\nabla|\nabla\theta||\,d\lambda}{\sqrt{2}} \tag{43}$$

$$|\nabla\theta_w| + \frac{a\,|\nabla|\nabla\theta_w||\,d\lambda}{\sqrt{2}} \tag{44}$$

frontal_zones.f

θ, θ_w frontal zones defined in Hewson, T., 1997, *Met. Apps.*, accepted.

$$\frac{\partial(\nabla|\nabla\theta|)}{\partial s} \tag{45}$$

$$\frac{\partial(\nabla|\nabla\theta_w|)}{\partial s} \tag{46}$$

fronts.f Frontal parameters defined in Hewson, T., 1997, *Met. Apps.*, accepted.

$$\nabla^2\theta_w \tag{47}$$

$$\nabla^2\theta \tag{48}$$

$$-\nabla|\nabla\theta|\cdot\left(\frac{\nabla\theta}{|\nabla\theta|}\right) \tag{49}$$

$$-\nabla|\nabla\theta_w|\cdot\left(\frac{\nabla\theta_w}{|\nabla\theta_w|}\right) \tag{50}$$

In addition, the following can be computed using the basic vector operations and derivative routines.

- Magnitude and components of $\nabla\theta$ and $\nabla\theta_w$

$$|\nabla\theta| = \sqrt{\left[\left(\frac{1}{a\cos\phi}\frac{\partial\theta}{\partial\lambda}\right)^2 + \left(\frac{1}{a}\frac{\partial\theta}{\partial\phi}\right)^2\right]} \tag{51}$$

$$| \nabla\theta_w | = \sqrt{\left[\left(\frac{1}{a\cos\phi}\frac{\partial\theta_w}{\partial\lambda}\right)^2 + \left(\frac{1}{a}\frac{\partial\theta_w}{\partial\phi}\right)^2\right]} \quad (52)$$

$$E - W \equiv \frac{1}{a}\left(\frac{\partial\theta}{\partial\lambda}\right) \quad (53)$$

$$N - S \equiv \frac{1}{a\cos\phi}\left(\frac{\partial\theta}{\partial\phi}\right) \quad (54)$$

- Advection and geostrophic advection of θ, θ_w, *viz.*

$$\mathbf{v}.\nabla\theta \quad (55)$$

$$\mathbf{v}.\nabla\theta_w \quad (56)$$

$$\mathbf{v_g}.\nabla\theta \quad (57)$$

$$\mathbf{v_g}.\nabla\theta_w \quad (58)$$

- Cross-front wind speed

$$(v \cdot \nabla | \nabla\theta |) / (\nabla | \nabla\theta |) \quad (59)$$

$$(v \cdot \nabla | \nabla\theta_w |) / (\nabla | \nabla\theta_w |) \quad (60)$$

(61)

qtannor.f

Computes q-vectors tangent and normal to θ

If ds is a unit vector tangent to a constant surface $\theta = c$ (i.e. $\nabla\theta$), then the resolved E-W and N-S components of ds are

$$E - W \equiv \frac{1}{a\cos\phi}\frac{\partial\theta}{\partial\lambda} \quad (62)$$

$$N - S \equiv \frac{1}{a}\frac{\partial\theta}{\partial\phi} \quad (63)$$

and the direction of ds, δ, is given by

$$\delta = \tan^{-1}\left(\frac{\cos\phi\frac{\partial\theta}{\partial\phi}}{\frac{\partial\theta}{\partial\lambda}}\right) \quad (64)$$

Further, define the magnitude of Q by

$$| Q | = \sqrt{Q_1^2 + Q_2^2} \quad (65)$$

and the angle β between the Q-vectors

$$\beta = \tan^{-1}(Q2/Q1) \quad (66)$$

Then the projection of $| Q |$ onto ds defines the Q-vectors tangent and normal to θ. Now define α as the difference between the two angles

$$\alpha = \beta - \delta \quad (67)$$

so that the components of Q-vectors tangent to θ are

$$E - W \equiv |Q| \cos\delta \cos\alpha \tag{68}$$
$$N - S \equiv |Q| \sin\delta \cos\alpha \tag{69}$$

and the components of Q-vectors normal to θ are

$$E - W \equiv -|Q| \cos\delta \sin\alpha \tag{70}$$
$$N - S \equiv |Q| \sin\delta \sin\alpha \tag{71}$$

F EXFIELD - UM DATA MANIPULATION UTILITIES

F.1 Introduction

Unified Model datasets are often too large to be loaded into, for example the idl graphics program JPLOT. For this reason a utility called exfield has been written which extracts a user defined subset of data from the UM data file. This subset of data can then be loaded into the graphics application. As a rough guide, if the UM data file is over 100Mb in size then exfield will probably be needed to produce smaller subsets of data. However, it really depends on the disk space and memory configuration of your system as to whether you need to use exfield.

The exfield script can extract data from both FIELDSFILE type and PP-format type files, by calling a different executable for each. If you have a RAL Cray account then you will be able to access my executables, whereas if you are working on a workstation then we will supply the source code but in this case exfield is only designed to work with PP-format files, so any Fieldsfile type files will need converting to PP format.

The extracted data may be written out either as a PP-format file or in a simple (IEEE 32-bit F77 Unformatted) manner, preceded by a simple header containing resolution and domain details, etc. These data file formats have been programmed into the JCMM IDL data visualisation program JPLOT so that an option exists for loading either of these UM Data files. Although JPLOT may only load PP-format files under certain restrictions. It is recommended that exfield is used to extract data and write it in PP-format as this is the most common UM file type.

With a suitable choice of parameters, these extracted data files can be used as input data for a JPLOT animation sequence; an example data extraction job to accomplish this is shown in Appendix F.5.

F.2 The EXFIELD script

A Unix Bourne shell script exists called exfield which supplies input data to the executable and runs it, and is shown in Appendix F.4. This data takes the form of 3 environmental variables, 2 namelists and lists of stashcodes (Met. Office defined integers signifying UM diagnostic fields) and associated dump indices (integers defining extraction times of UM data). The environmental variables are:

1. OUT - Indicates the root filename of the output from qxfield.f, i.e. if OUT=test, then the output data will appear in test.dat, a file called test.head will also appear which contains a line describing each entry of the UM data file. In general 2 output files will be generated, $OUT.dat containing the extracted data and $OUT.head containing a 'table of contents' of the UM input file.

2. EXPTID - This indicates the UM experiment ID and has been included for convenience and can be used in defining the UM data filename (see below).

3. FORM - This indicates the UM file structure, i.e. set to FIELDSFILE or PPFORMAT, and hence determines which executable is called.

The first namelist called DATAFILE contains 4 variables:

1. INFILE - The full pathname of the UM data file to be read in.

2. HEADER_ONLY - Specify 1 to read the UM input file header information only, the parameters in the second namelist are ignored and no data is written to $OUT.dat. The file $OUT.head contains 1 line for each entry in the UM data file, with information such as Stashcode (reference No. of field) NX, NY, dump times etc. Therefore this option is useful to find out exactly which fields are contained in the UM data file.

3. IFORM - Only relevant for 'PP-format' files and should be set to 1 for a formatted file or 0 for unformatted.

4. IEEE - This parameter indicates whether the UM file is of IEEE type, i.e. set to 1 if so, else 0.

The second namelist called DUMP contains 13 variables:

1. NLEVS - Set this to the number of model levels associated with the current UM data file. At present the program will write out the relevant field on all the levels it is stored on in the UM dataset, whether it be model levels, pressure levels or a single level ancillary field. (N.B. see NLEVMAX) This parameter must be set correctly since it is used by JPLOT to dimension data storage arrays.

2. NLEVMAX - This parameter will enable selection of the subset of model levels (1,....,NLEVMAX) for fields defined on model levels and will have no effect on fields defined on pressure levels. To disable please set NLEVMAX to NLEVS.

3. NMLV - No. of multi-level fields required for extraction.

4. NSLV - No. of single-level fields required for extraction.

5. MLEV_ANIM - The index of the model level required for the animation sequence, (see Appendix F.5), set to zero if not required.

6. PLEV_ANIM - The index of the Pressure level required for the animation sequence, (see Appendix F.5), set to zero if not required.

7. ANCIL - set to 1 or 0 to indicate the reading of an UM ancillary data file.

8. NO_HEADERS - set to 1 or 0 to indicate if you require the 'turning off of all headers' in the extracted data file, i.e only field data will be present in the output, and the file will not be suitable for loading into JPLOT. Hence the extracted data file contains a sequence of f77 unformatted records, with 3D fields written out a level at a time.

9. TINDX_TYPE - set to 1 to indicate that the dump indices are supplied in the usual 'list' format. Set to 2 to indicate the dump indices are supplied in a way analagous to Fortran DO Loop index specification, (see Appendix F.6).

10. SUB_FIELDS - set to 1 or 0 to indicate if you require the writing out of a sub-portion of the whole field. If set then all fields will be output in this way, and according to: field(nx1:nx2,ny1:ny2) where nx1,nx2,ny1,ny2 should be supplied in that order on a line after the field codes and dump indices have been specified.

11. CHOOSE_MLEVS - set to 0 (the default) to enable the program to output fields defined on Model levels to be written out on all the Model levels present (subject to MLEVMAX). Set to > 0 to indicate the number of Model levels required for output, the required Model levels are selected by further specification of an array MLEV_INDS(1:CHOOSE_MLEVS) containing indices specifying the Model level number, this array should follow the sub-field indices (if present). For example, set CHOOSE_MLEVS=5 and MLEV_INDS=[1,2,4,10,11] to select data on Model levels 1,2,4,10 and 11.

12. CHOOSE_PLEVS - set to 0 (the default) to enable the program to output fields defined on Pressure levels to be written out on all the pressure levels present. Set to > 0 to indicate the number of pressure levels required for output, the required pressure levels are selected by further specification of an array PLEV_INDS(1:CHOOSE_PLEVS) containing indices specifying the pressure level, this array should be the last input record the program reads on Fortran unit 5, i.e. it should come after the selected Model indices (if present). For example, if field data is held on pressure levels 1000, 950, 900, 850 and 800 mBar then set CHOOSE_PLEVS=3 and PLEV_INDS=[1,2,4] to select data on pressure levels 1000, 950 and 850 mBar.

13. PPF_OUT - set to 1 to have exfield write out the extracted data in the form of a PP-format file rather than a UM data extraction file specifically for loading into JPLOT.

This namelist is then followed by arrays of integer Stashcodes of the fields required for extraction from the data file, along with their associated dump indices (the format of these depending on the TINDX_TYPE parameter in the above namelist), in comma separated format (i.e. '*' format). The stashcodes are very important as they uniquely define a field, a list of common stashcodes can be found in Appendix C. The description immediately below assumes that TINDX_TYPE=1. Each series of stashcodes is followed by the corresponding series of dump indices NDUMP. These numbers are frequency indices of the dumped fields appearing in the data file for each stashcode (diagnostic field) requested, i.e. the data file may contain the same data field dumped at a number of times. e.g. if a particular field (I) is dumped at times of 1.0, 3.0, 5.0 hours, then to extract the field at 5.0 hours, set NDUMP(I)=3. N.B. some ancillary files contain a field for every month of the year, so to extract the field valid in June, for example, set NDUMP(I)=6. The arrays of stashcodes and dump indices should be arranged as below.
If NMLV > 0:

STASHCODE(I), I=1,NMLV.
NDUMP(I), I=1,NMLV.

If NSLV > 0:

STASHCODE(I), I=NMLV+1,NMLV+NSLV.
NDUMP(I), I=NMLV+1,NMLV+NSLV.

However, if TINDX_TYPE=2 then the dump indices are entered as follows. The first integer in the list indicates the number of groups of 3 integers that follow in the input record. i.e. the groups of 3 integers indicate the starting index, final index, and index increment. This is useful when extracting the same field at a number of different times, and when extracting animation sequences. See Appendix F.6 for an example.

N.B. When the value of one of the above parameters is expected as either 0 or 1, i.e. the option is switched off or on, the program has a default value of 0 indicating the option is off. Therefore if the option is not required then the corresponding variable may be omitted from the namelist.

F.3 Running the Script

Firstly if you have a Cray account at RAL then once you have obtained the exfield script you will be able to access my copies of the executables so there is no need for any compilation. However, if you want to run exfield on a workstation (and therefore read PP-format files only) you will need to compile some fortran code viz:

```
f77 -o sort.x sort.f
```

The exfield script produces output to the screen which will indicate whether the job has proceeded without error, it is probably best to redirect this to a file, i.e. to run exfield, type

```
sh exfield > output
```

It is advisable to check the contents of 'output' to see if the fields requested were successfully extracted. If you use the Bourne shell then you can leave out the 'sh'. If the job has proceeded correctly the 32-Bit unformatted Fortran output file $OUT.dat is now ready for transfer to the local system (using ftp), ready for loading into the IDL program JPLOT.

An example job to extract UM data is shown in Appendix F.4. This job processes 3 multi-level and 2 single-level fields at various dump times from the UM data file. More specifically:

- Multi-level field 15201 (U Velocity on Pressure levels) at the first dump time.
- Multi-level field 15202 (V Velocity on Pressure levels) at the first dump time.

- Multi-level field 5212 (Convective cloud amount on Model levels), however as NLEVMAX is set to 10, only the first 10 levels are extracted, at the third dump time.
- Single-level field 3225 (10 m U-wind) at the second dump time.
- Single-level field 3226 (10 m V-wind) at the second dump time.

F.4 A Listing of EXFIELD

```
# EXFIELD: EXTRACTS DATA FROM UM DATASETS (Cray Version)
# In either of these formats:
# 1) PP-format (PPF_OUT=1)
# 2) UM Data extract (PPF_OUT=0)
#
SPATH=/home/j90/emd/umod
OUT=test    # root filename for output
EXPTID=t2    # UM experiment ID
OUTPUT=$OUT.dat
HEADER=$OUT.head
FORM=FIELDSFILE    # set type of UM file FIELDSFILE or PPFORMAT
#
# Supply the following input data
# A) Parameters in DATAFILE namelist
# 1) output file (PP file/dump) name or ancillary file name
# 2) Integer switch (1 or 0) for reading header information only
# 3) switch indicating f77 formatted/unformatted (PPFORMAT only)
# 4) switch indicating whether file is IEEE
# B) Parameters for DUMP namelist
# 1) NLEVS: No of model levels
# 2) NLEVMAX: Max No of model levels to be written
# 3) NMLV: No of multi-level fields required
# 4) NSLV: No of single-level fields required
# 5) TINDX_TYPE: Dump Indices- 1 for list, 2 for start,end,incr.
# 6) MLEV_ANIM: Model level index for animation sequence
# 7) PLEV_ANIM: Pressure level index for animation sequence
# 8) ANCIL: Integer switch to indicate reading of an ancillary file
# 9) NO_HEADERS: Switch indicating no writing of any headers
# 10) SUB_FIELDS: Switch indicating sub-region for all fields
# 11) CHOOSE_MLEVS: Switch setting no. of Model levels for output
# 12) CHOOSE_PLEVS: Switch setting no. of Pressure levels for output
# C) STASH codes and DUMP indices
# 1) STASH codes for multi-level fields (if NMLV>0) ('*'format)
# 2) Corresponding dump time indices in UM file
# 3) STASH codes for single-level fields (if NSLV>0) ('*'format)
# 4) Corresponding dump time indices in UM file
# N.B for ancillary files with monthly versions of a field
# ndump is the no. of the month for which data required
#
DFILE="/home/j90/emd/umod/datar/example.pp1"
cat > fort.5 << EOF
&DATAFILE
INFILE=$DFILE,HEADER_ONLY=0,IFORM=0,IEEE=1
&END
```

```
&DUMP
NLEVS=19,NLEVMAX=10,NSLV=2,NMLV=3,ANCIL=0,
TINDX_TYPE=1,MLEV_ANIM=0,PLEV_ANIM=0,PPF_OUT=0,
NO_HEADERS=0,SUB_FIELDS=0,CHOOSE_MLEVS=0,CHOOSE_PLEVS=0
&END
15201,15202,5212
1,1,3
3225,3226
2,2
EOF
if [ "$FORM" = "FIELDSFILE" ]; then
EXEC=$SPATH/exfield.x
else
EXEC=$SPATH/sort.x
fi
$EXEC < fort.5
mv fort.12 $HEADER
# prepend data with integer header information
cat fort.20 fort.21 fort.22 > $OUTPUT
exit 0
```

F.5 Animation Sequences

When extracting data suitable for a JPLOT animation sequence, the basic idea is to extract the same field at a given level at many dump times. This means that only 1 Stashcode may be supplied, but at many values of the dump index. The parameters MLEV_ANIM and PLEV_ANIM, in the input namelist DUMP, select which level the sequence is required at. If you do not require animation sequences then set MLEV_ANIM and PLEV_ANIM both to zero. Hence if a field defined on model levels is required for animation then set MLEV_ANIM to the required level index. In the case of a field defined on Pressure levels then set PLEV_ANIM to the required index 1,2, etc. rather than the actual value of the Pressure level in mB. In the case of a single level field then set MLEV_ANIM=1. N.B. one of MLEV_ANIM and PLEV_ANIM must be set to zero.

The example below shows the settings of the parameters in the input namelist DUMP and the Stashcodes and dump indices required to extract data suitable for a JPLOT animation sequence. The field extracted (15201) is U-Wind on Pressure levels, on Pressure level index 2, and at the 2^{nd} to 11^{th} dump times in the UM data file:

```
&DUMP
NLEVS=19,NLEVMAX=19,NSLV=0,NMLV=10,ANCIL=0,
TINDX_TYPE=1,MLEV_ANIM=0,PLEV_ANIM=0,
NO_HEADERS=0,SUB_FIELDS=0
&END
10*15201
2,3,4,5,6,7,8,9,10,11
```

F.6 Use of TINDX_TYPE=2

The example below shows how to request fields at a number of different dump times, the stashcode and dump indices entered might for example look something like:

```
5*15201,5*15202,6*16222
3,1,5,1,1,5,1,2,12,2
```

The fields being extracted are U, V and PMSL. The first entry in the dump index list is the number of sets of 3 integers that follow in that input record, i.e. 3 in this case. The first 2 sets of 3 integers that follow are the same (i.e. 1,5,1) and mean that for the U and V fields the dump indices required start at 1 and end at 5 with an increment of 1 and so are given by 1,2,3,4,5. The PMSL field trio of entries in the dump index list (2,12,2) mean that the dump indices required are 2,4,6,8,10,12.

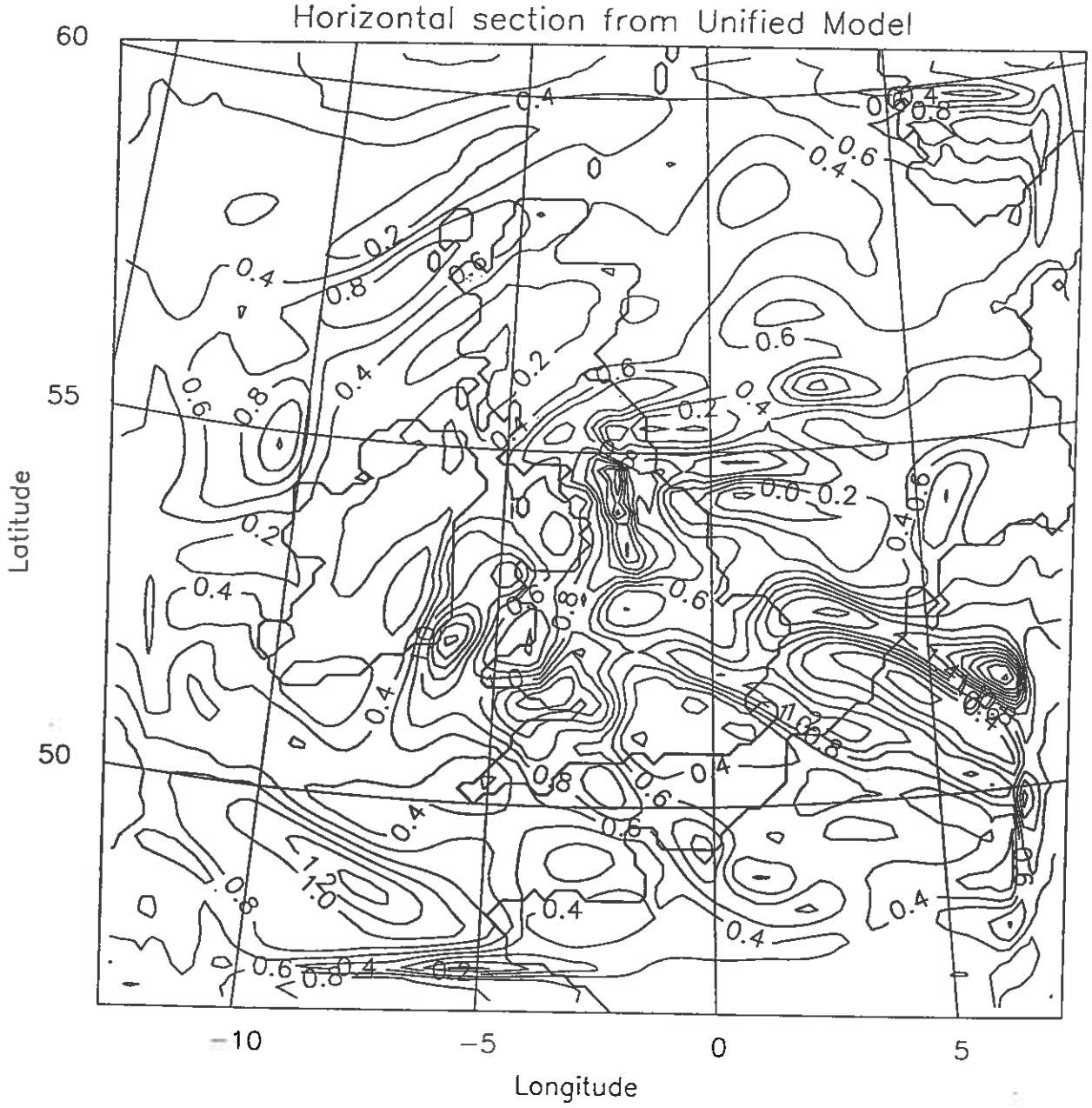

Figure 11: A horizontal section of Potential Vorticity (PV) at a pressure level of 700 mBar forecast at T+6 from 0Z on 17/5/96. The contour increment is in PV units, i.e. $0.2X10^{-6}Kkg^{-1}m^2s^{-1}$.

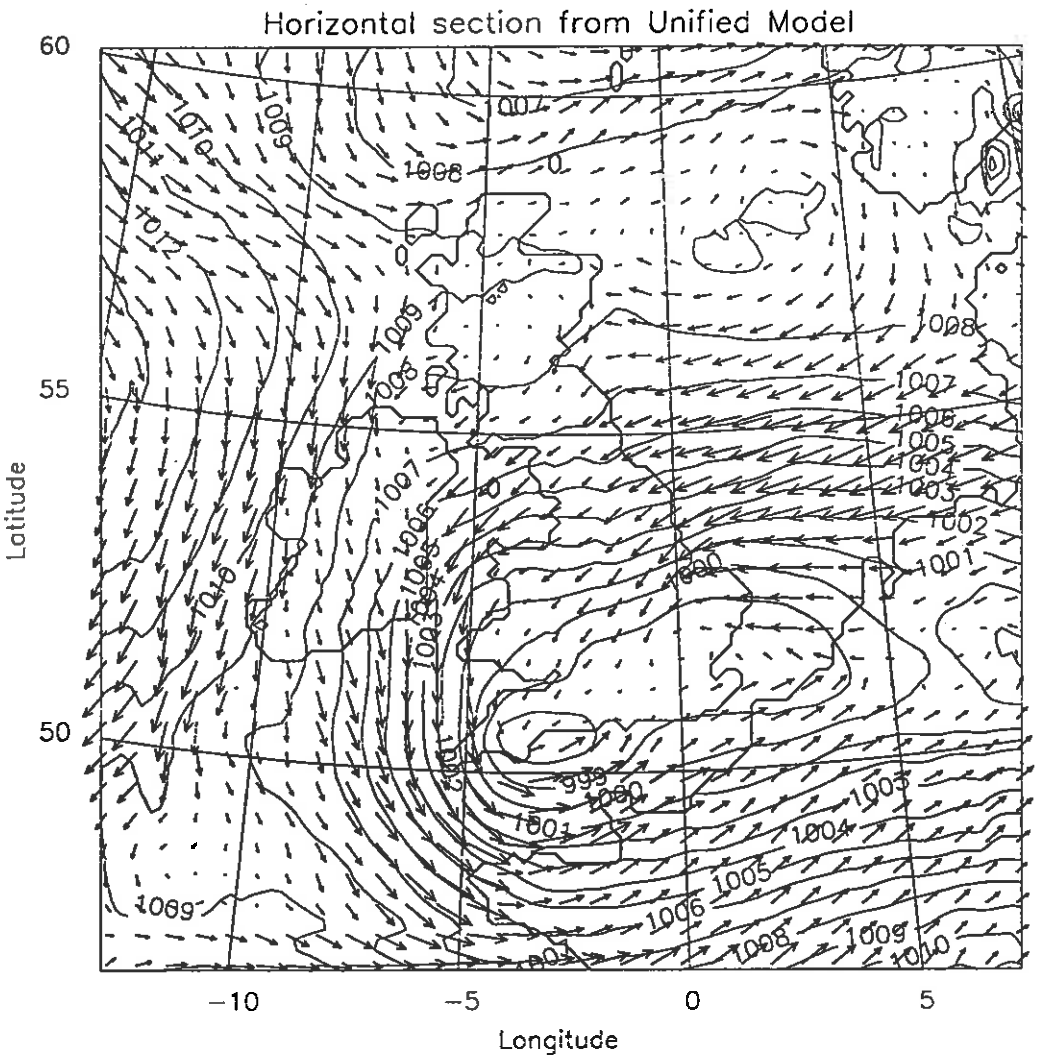

Figure 12: A contour plot of PMSL forecast at T+6 from 00Z on 17/5/95, with wind vectors at 1000 mb overplotted, PMSL contour interval: 1 mb

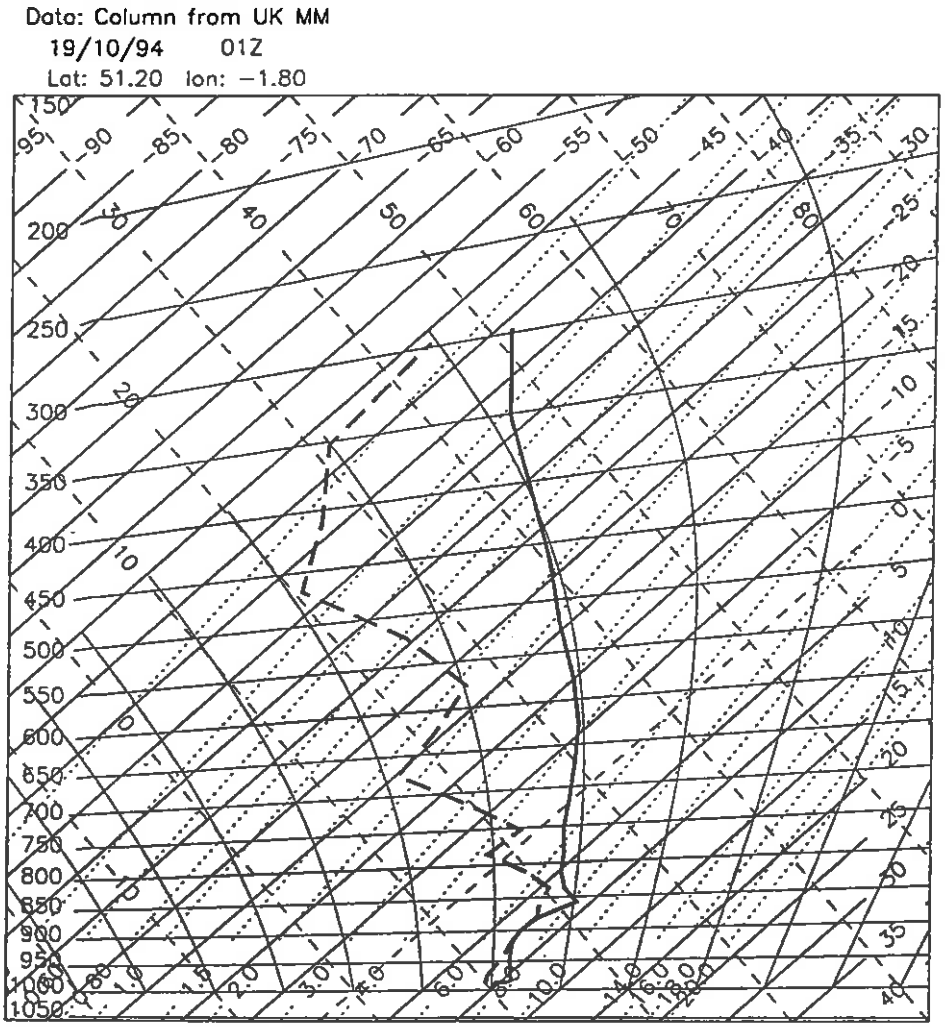

Figure 13: A tephigram plot created using the integrated tephigram creation facility (from UM data) which JPLOT posseses. The UM data is at 0Z on 19/10/94. The tephigram creation facility may also be used as a stand-alone program to plot tephigrams from non-model data.

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69. **Met. Office Unified Model data, diagnostics, graphics programs, and other observational data available from the JCMM through the aegis of the Universities Weather Research Network (UWERN).** (Plus supplement)
Peter Panagi and Ed Dicks
June 1997

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INTERNAL REPORT 69 SUPPLEMENT

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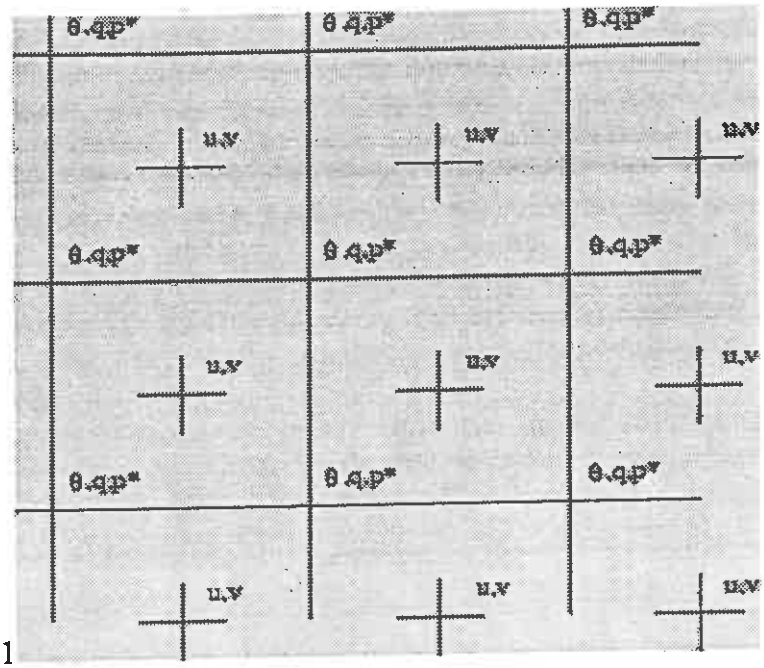


Figure 1

Over land a geographical distribution of vegetation and soil types is specified. These determine soil conductivity and heat capacity, surface hydrology, albedo and roughness. The last two parameters are allowed to vary if the surface acquires snow cover.

In atmosphere-only mode, sea-surface temperatures are specified from analyses updated every day and sea-ice cover is specified from climatology, supplemented by observational data where available. Sea-ice thickness is set to 2m.

Unified Model equations

The model integrates forward the hydrostatic primitive equations of motion. These have been revised to include terms which ensure that the finite difference approximations remain accurate on planetary scales, and include a complete representation of the Coriolis effect. Within the scheme mass and mass-weighted potential temperature are conserved, as is angular momentum.

Parametrisation of atmospheric and surface processes

The physical parametrisation schemes are all based on those used in the previous Met. Office Climate Model, where they have been found to produce a realistic climate when applied over long periods. They are more detailed than those used in previous NWP models.

Sub-surface, surface and boundary-layer processes

As previously mentioned, land points are allowed varying characteristics according to soil and vegetation type. A soil model containing four layers is used to represent the sub-surface heat fluxes. heat balance equation is used to derive the surface temperature and contains terms for the fluxes of incoming solar radiation, outgoing long-wave radiation, sensible heat down into the soil and up into atmosphere and latent heat due to the evaporation of water and the melt of snow. The presence changes the surface albedo and roughness length, as well as insulating the soil. Surface water

increased by precipitation, condensation and snow-melt, and decreased by evaporation, surface run-off and seepage into the deep soil.

The vegetation canopy plays a part in the hydrology of the model in several ways: It provides a source of moisture to the atmosphere through evapo-transpiration; it acquires and stores water by intercepting falling rain and by direct condensation; it releases this water to the soil by the process of "throughfall". Turbulent mixing plays an essential role in determining the structure of the boundary layer, and occurs on scales far smaller than the models' resolution. It determines important fluxes of sensible heat, moisture and momentum between the surface and the atmosphere. Its effects are calculated using equations of diffusion (analogous to conduction).

Over the sea roughness length increases with increasing wind to represent the interaction of waves with the flow of the atmosphere. Sea-surface currents are used to determine the wind speed relative to the surface water in these calculations (Fig 4).

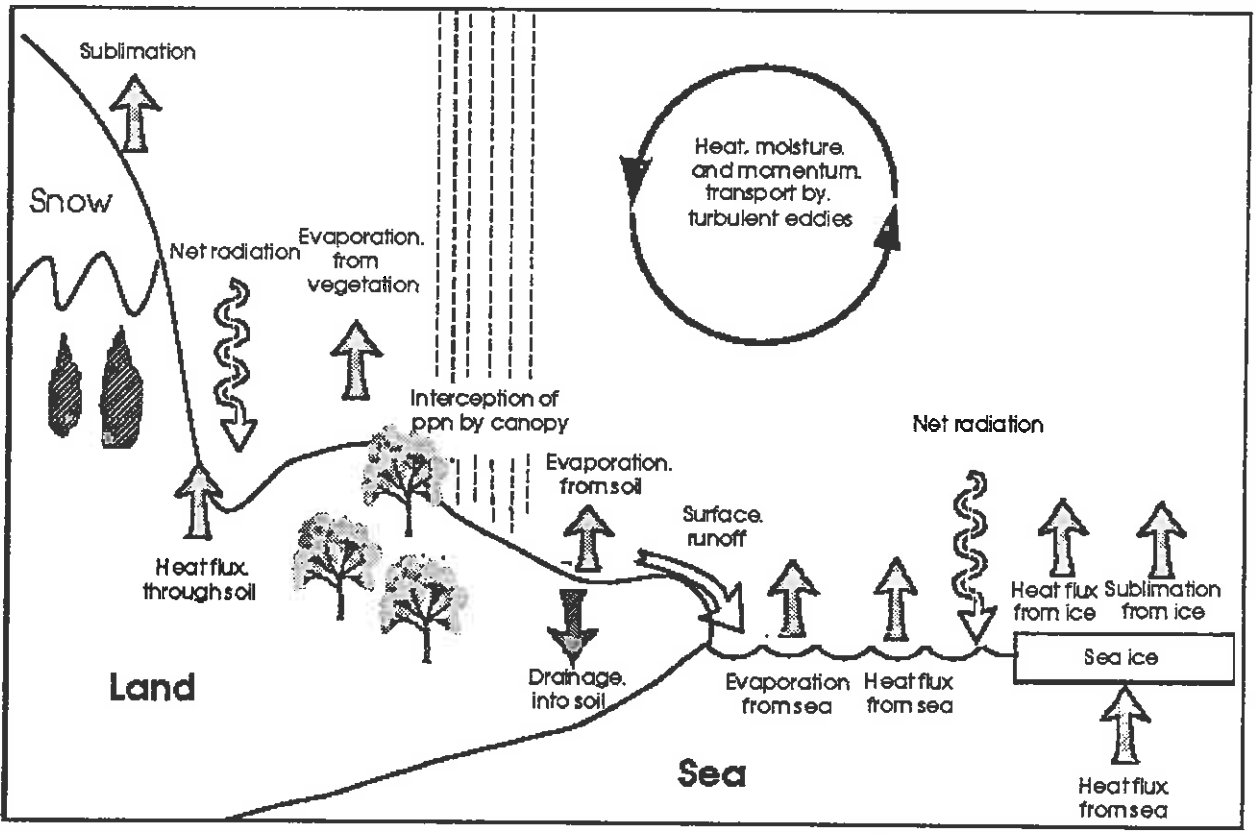


Figure 4

Large-scale cloud and precipitation

The model holds explicit values of fractional cloud cover, together with separate values for cloud water and cloud ice mixing ratios (i.e. kg of cloud water/ice per kg of moist air within a cloud). Cloud water is converted to precipitation by a process known as autoconversion, the rate of which increases with increasing cloud water mixing ratios. The autoconversion equation includes a term which increases the rate of conversion if there is precipitation falling into the grid-box from above, thereby simulating the processes of growth by accretion and coalescence. In this way seeder-feeder enhancement of precipitation may be represented. Frozen precipitation is assumed to start falling as soon as it is formed,

16 levels. A hybrid pressure based co-ordinate is used, referred to as SYMBOL 104 \f "Symbol" (eta) (Fig. 3). The more detailed Mesoscale Model however has 31 levels.The bottom four levels are terrain-following sigma levels, which help in application of realistic boundary conditions. The top three levels are pressure surfaces, and in between the levels are a mixture of the two, so that they gradually follow the terrain less and less and become more uniform in pressure with height.

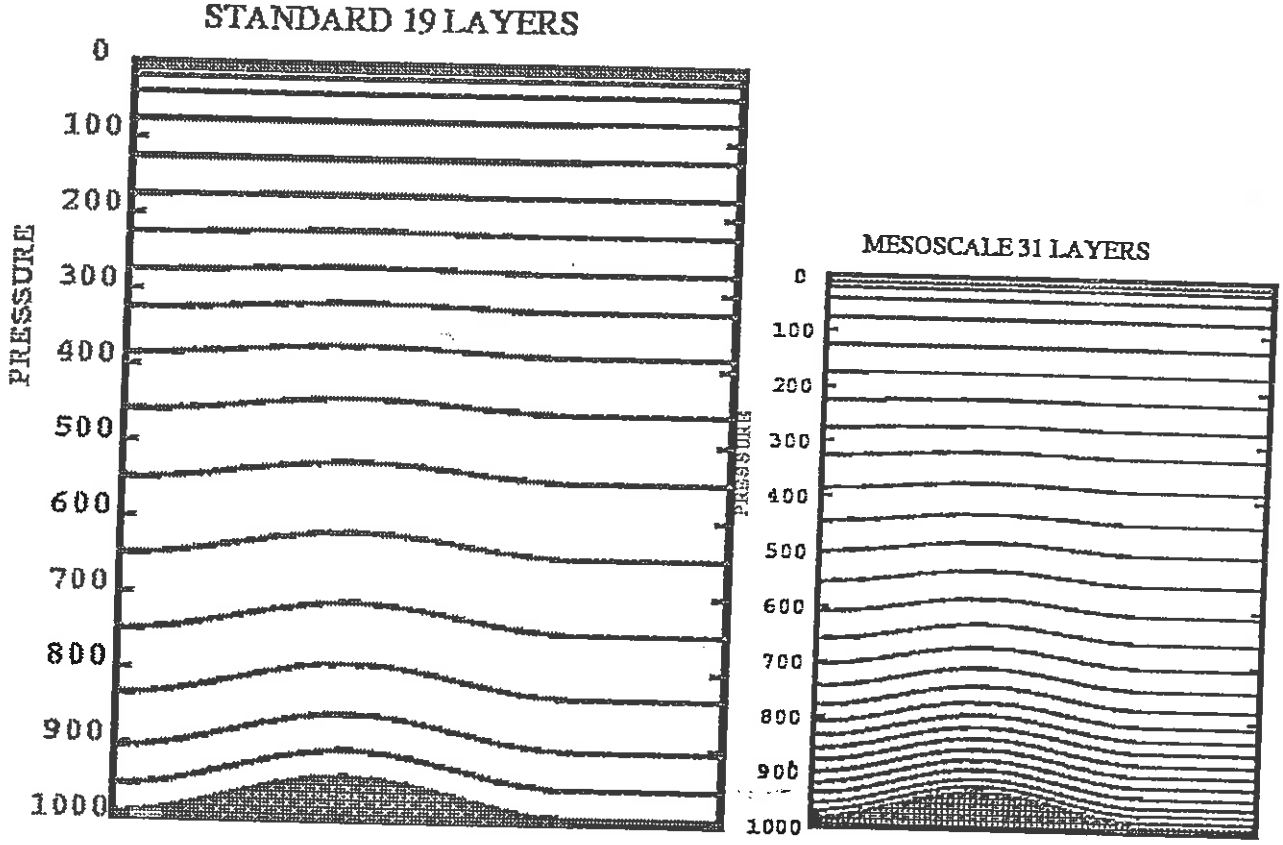


Figure 1

Resolution is greatest near the surface in an attempt to model the rapid variations here. The first layer is thinnest, being about 50m thick. Layers above the boundary layer are 1 to 1.3km thick, increasing to in excess of 2km at around 12km. The topmost level is at 40km, in the upper stratosphere. The number of grid- points for each model is given in Table 1.

Model	No. of grid-points	Grid Size
Global	1,187,424	288 x 217 x 19
Limited Area	574,332	229 x 132 x 19
Mesocale	262,384	92 x 92 x 31

Table 1 - Number of grid-points in each model

Model variables and ancillary fields

The atmosphere models predict the following primary prognostic variables:

a) Horizontal wind components (u,v)
b) Potential temperature (theta)
c) Specific humidity (q)
d) Cloud water and ice (ql, qf)

e) Surface pressure (p*)
f) Soil temperature (TS)
g) Soil moisture content (SMC)
h) Canopy water content
i) Snow depth (Snowdep)
j) Surface temperature (T*)

From which the following secondary prognostic variables may be diagnosed:

k) Boundary layer depth (ZH)
l) Sea surface roughness (ZO)
m) Convective cloud amount (CCa)
n) Convective cloud base (CCb)
o) Convective cloud top (CCt)
p) Layer cloud amount (Ca)
q) Vertical velocity (SYMBOL 104 \f "Symbol")

When run in coupled ocean/atmosphere configurations, the following are included as additional prognostic variables:

r) Sea surface temperature (SST)
s) Proportion of sea-ice cover (ICEc)
t) Sea-ice thickness (ICEt)
u) Sea surface currents

Ancillary fields (i.e. those parameters that are not predicted and must be specified) include:

v) Land/sea mask
w) Soil type
x) Vegetation type
y) Grid-box mean and variance of orography
z) Ozone mixing ratio

When run in atmosphere only mode, parameters r) to u) are included as ancillary fields rather than prognostic variables and must be specified.

If the model is run with limited horizontal extent, boundary values of prognostic variables a) to e) must be supplied for the period of the integration.

If the model is run with limited vertical extent, for example as a stratospheric model, prognostic variables f) to p) are not used, and item z) is the only ancillary field used. For some applications item z) may be a prognostic variable.

Variables within the model are held on an Arakawa B-grid. As shown in Fig 1, this means that the components of the horizontal wind are offset from the other primary variable and are located at the centre of a grid box.

- A history file containing a record of the run
- A final data set
- Mean data sets in the same form as a final data set
- Sequential data sets in a form suitable for further processing by diagnostics programs

Co-ordinate systems and resolution

The operational Global Model is a grid-point model using a standard latitude/longitude co-ordinate system with grid points every 5/6 (0.8333) degrees latitude and 5/4 (1.25) degrees longitude. This gives a north-south resolution of 93km and an east-west resolution that decreases with increasing latitude. On the equator it is 139km and at 50 latitude it is 89km, so that in these regions the grid boxes are almost square. Poleward of around 55 the extra east-west resolution is not effective as the fields must be filtered to remove spurious small scale variations that develop as a result of close grid spacing. This limits the effective resolution to around 93km.

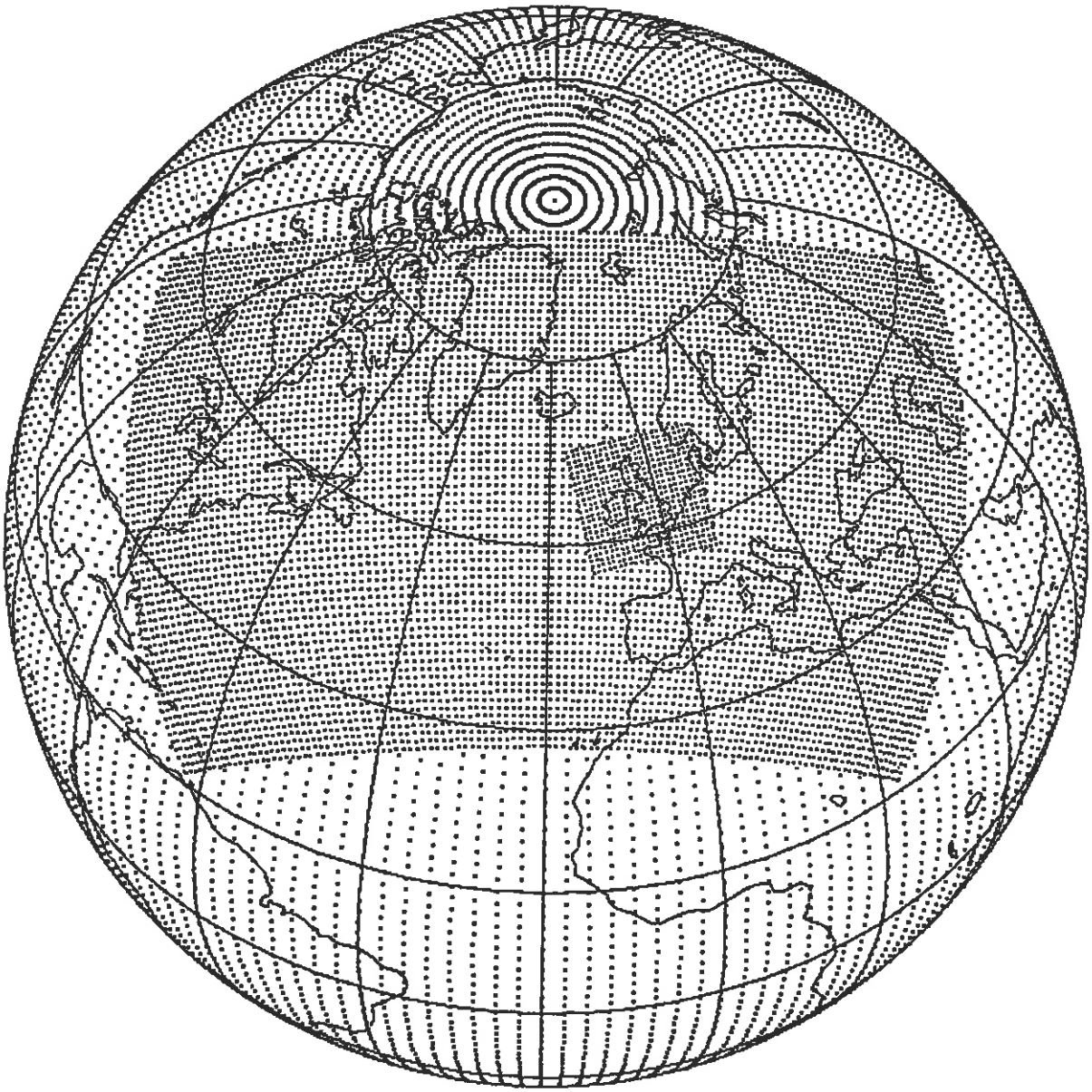


Figure 1

Instead of a grid based on actual latitude/longitude co-ordinates, the Limited Area version uses a rotated latitude/longitude co-ordinate system in which the computational north pole is shifted to an actual position of 30 N 160 E (Fig. 2). This allows the regional area to take advantage of the even grid spacings enjoyed in equatorial regions, and dispenses with the need to filter. It is sometimes referred to as an ELF grid (Equatorial Lat-long Fine-mesh). The rotated grid has a resolution of 0.4425 degrees in both directions, which equates to about 50km across the whole area.The model may be run in limited area format for any other part of the globe, as long as the co-ordinate pole is shifted to a position such that the area of interest has even grid spacing.

"The model may be run in limited area format for any other part of the globe"

Both the Global and Limited Area Models have the same resolution in the vertical. The atmosphere is divided into 19 layers, with winds and temperatures carried at 19 levels and humidity carried at the first

Part I

ATMOSPHERIC FORMULATION AND NUMERICAL WEATHER PREDICTION

Atmosphere Formulation and Numerical Weather Prediction

Based on NWP Gazette Vol 1 article by Mike Longworth

Author A. Dickinson: Version 1. 22/12/94

Introduction

The Unified Model is so called because it combines and standardises:

- Operational Numerical Weather Prediction (NWP) models in both global and limited area formats
- Climate modelling
- Ocean modelling

It achieves this aim by using a single general purpose code and employing a modular structure which allows easy enhancements to, and interchange between, models. Furthermore, all the meteorological code has standard interfaces between subroutines as agreed by several centres in Europe and the USA, to facilitate the exchange of physical parametrisation schemes for intercomparison. The code has also been written so that it is not machine dependent, facilitating its transfer to other computer systems and its use by external research institutes.

The Unified Model is designed to run in a number of different configurations, the three main ones being:

- Atmosphere only
- Ocean only
- Coupled ocean/atmosphere

Currently only climate experiments are run in coupled mode, but there are long-term plans to extend its use to operational NWP. The model may be run with either a global domain, or one that is limited in horizontal or vertical extent. For day-to-day NWP there are three atmosphere-only versions: a Global Model, covering the whole world; a Limited Area Model, covering much of Europe, the North Atlantic and North America; and finally a Mesoscale Model, covering the UK and a small part of Continental Europe. (fig 1). They all share the same physical parametrisations, a feature that was not the case with their previous counterparts.

Boundary conditions for the Limited Area Model (LAM) are provided by Global Model (GM) forecast values from an earlier run interpolated on to the Limited Area model co-ordinates. These are applied to the outermost four points around the boundaries, with weights given to global model values of 1, 0.75, 0.5 and 0.25. Similarly the LAM provides boundary values for the UK Mesoscale Model.

In order to speed up the availability of forecast products and increase the flexibility of the output system, the handling of model output is included within the Unified Model formulation. It can provide as output:

simulating enhanced growth by deposition (Bergeron- Findeisen). Evaporation and melting of precipitation is allowed to take place to the extent that the temperature and humidity of lower layers allow, with the attendant cooling of the environment by latent heat exchange. At temperatures of -15 C and below, all cloud content is ice, with a mixture of water and ice between -15 and 0 C, the proportion of ice decreasing with increasing temperatures.Dynamical ascent is the most important process leading to cloud formation in the model, but cloud may also be formed by radiative cooling and turbulent transport (Fig 5).

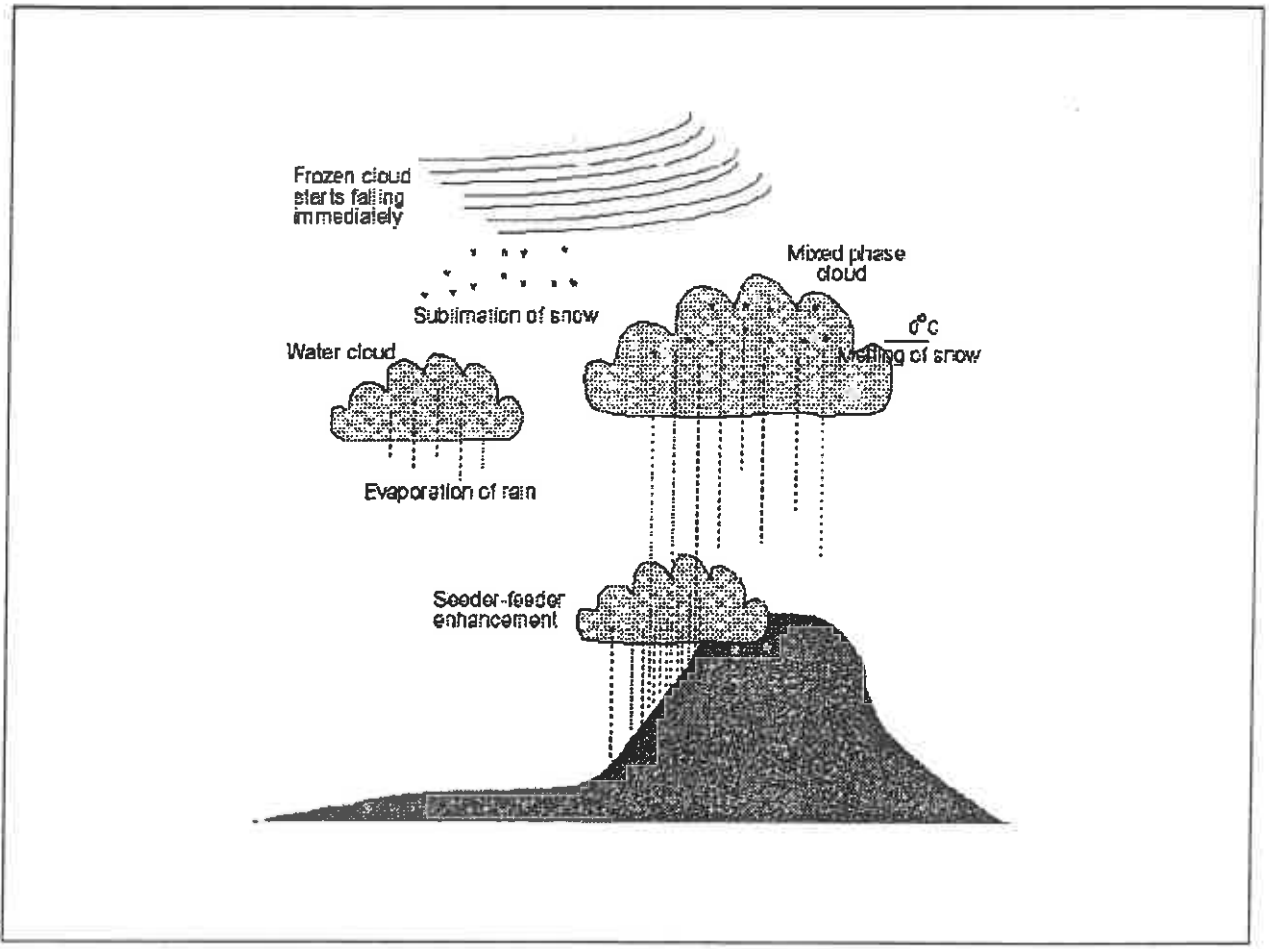


Figure 5

Convection and convective precipitation

A cloud model is used to represent cumulus and cumulonimbus convection, in which an updraught and precipitation-induced downdraught are considered. A test is made for convective instability: if the potential temperature of any level is higher than that of the level above, convection is initiated. Convection will continue as long as the air within the cloud continues to be buoyant. Dilution of the cloud is represented by entrainment of environmental air. Before the cloud detrains completely at the level where the parcel of air ceases to be buoyant, the remaining mass, heat, water- vapour and cloud water/ice are completely mixed into the environment at the cloud top. A single cloud model is used to represent a number of convective plumes within the grid square, and precipitation is diagnosed within that square if: (i) cloud liquid/ice content exceeds a critical amount and(ii) the cloud depth exceeds a critical value.

This value is set to 1.5km over the sea and 4km over land. However, if the cloud top temperature is less than -10 C, the critical depth is reduced to 1km over land or sea. As with large-scale precipitation, the convection scheme allows for evaporation and melting of precipitation (Fig 6).

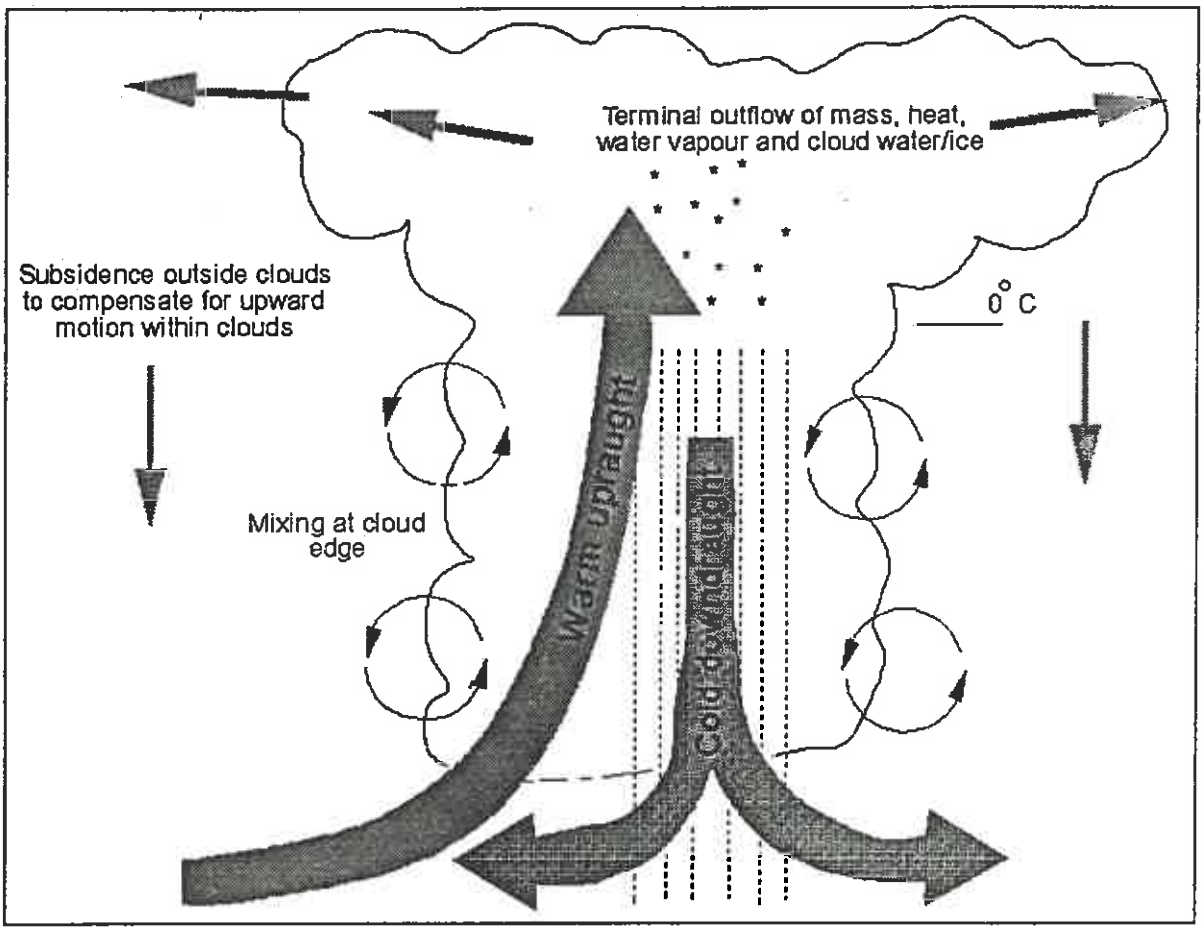


Figure 6

Radiative processes

The parametrisation scheme simulates heat transfer due to radiative fluxes, which may be divided into two types: short-wave due to incoming solar radiation and long-wave due to emissions from atmospheric gases, clouds and the earth's surface. Short-wave fluxes depend principally on the solar zenith angle (varying according to latitude, season and time of day), cloud and the albedo of the surface. Long-wave fluxes depend upon the amount and temperature of the emitting medium and its emissivity. The effects of each radiatively active constituent of the atmosphere (water vapour, carbon dioxide and ozone) are quite different and must be calculated separately. For this reason long-wave radiation is considered in six wavebands and short-wave in four. Clouds interact to a significant degree with both long and short-wave radiation. They are treated as homogeneous plane-parallel slabs, and in any grid-square a number of layers are allowed together with one convective tower. Their effects depend upon fractional cover, height, phase and water/ice content. "Dynamical ascent is the most important process leading to cloud formation in the model" Radiative heating and cooling rates are highly dependent upon water, in the form of both vapour and cloud/ice water content. Unfortunately the water substance as a whole is

poorly observed in the atmosphere and therefore the least well- forecast of all primary model variables. Surface albedo (i.e. the proportion of incident solar radiation reflected) depends upon vegetation and soil type, together with the distribution of sea-ice and snow cover. Because the parametrisation scheme is so complex, a short cut is taken in that the fluxes are only calculated once every three hours of model time (Fig 7).

Gravity wave drag

The Unified Model includes a scheme to parametrise gravity wave drag, whereby flow over mountains in stable conditions excites waves. Stress exerted is proportional to the sub-gridscale variance of topography and the wind speed. The waves are allowed to propagate vertically, reducing static stability by ascent and increasing wind- shear, until the Richardson's Number falls below a critical value. Where it does so "breaking" of the wave is diagnosed and a drag is exerted, leading to a brake on atmospheric flow. This represents the outbreak of turbulence with the onset of shear instability, where small scale turbulent motions feed off the kinetic energy of the large scale flow. Breaking has been shown to occur most commonly in the boundary layer and in the lower stratosphere, where isentropic surfaces are tilted and overturned. The effect is largest over mountains in winter, where it reduces the strength of jet streams and causes surface depressions to be less deep and quicker to fill than would otherwise be the case (Fig 8).

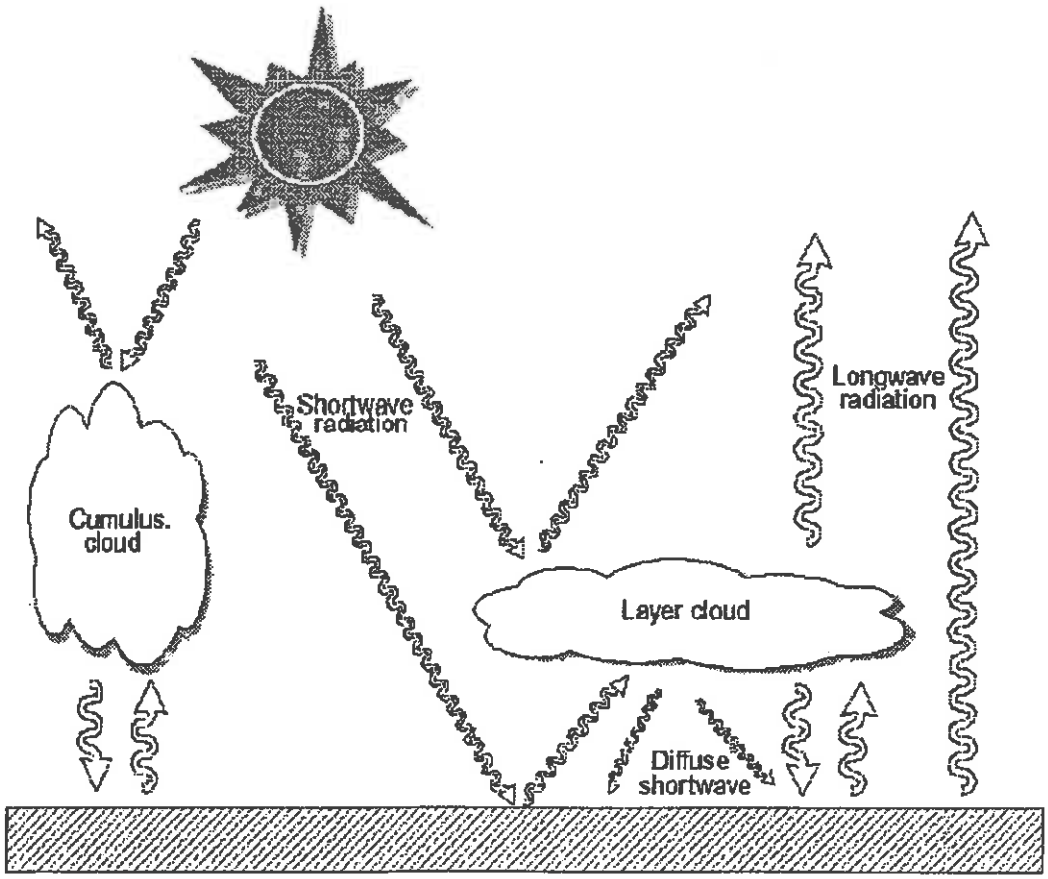


Figure 8

Operational schedule

The Unified Model employs a continuous assimilation technique whereby observations are repeatedly inserted into an evolving model around their validity time. The Global Model operates on a 6 hour cycle, assimilating data in forecast mode whilst integrating the fields forward in time to provide the background for the next run (Table 2). The Limited Area model operates on a 3 hour cycle, i.e. T+6 forecasts are made every 3 hours to provide the background field for the next run. A forecast out to T+36 is made at 02Z, 08Z, 14Z and 20Z, the latest Global Model run providing boundary conditions during the forecast. For the 12Z and 00Z runs, this is the Global Model run which starts from a data time 12 hours earlier, while for the intermediate runs it is 6 hours earlier.

0320Z
: First analysis centred on 00Z. Global Model run to T+144 (6 days)

1120Z
: Second analysis centred on 00Z to catch late data. Global Model run to T+6 to provide background field for 06Z analysis, accepting data throughout in continuous assimilation.

1200Z
: Analysis centred on 06Z. Global Model run to T+6 accepting data in continuous assimilation to provide background field for analysis centred on 12Z run.

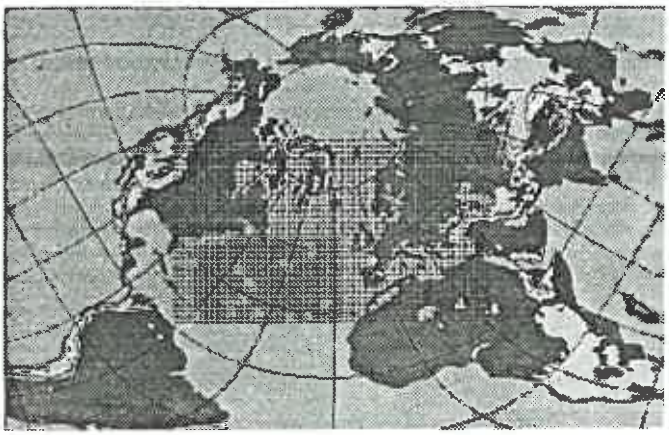
1520Z
: Repeat of 0320Z but with data around 12Z.

2320Z
: Repeat of 1120Z but with data around 12Z.

0000Z
: Repeat of 1200Z but with data around 18Z.

Table 2 Global Model operational cycle

Part II
THE UNIFIED MODEL



The Unified Model

1. Overview

The Unified Model is the name given to the suite of atmospheric and oceanic numerical modelling software developed and used at the Met Office. The formulation of the model supports global and regional domains and is applicable to a wide range of temporal and spatial scales that allow it to be used for both numerical weather prediction and climate modelling as well as a variety of related research activities. The Unified Model was introduced into operational service in 1991. Since then, both its formulation and capabilities have been substantially enhanced.

The modelling system is designed so that it can be run in atmosphere-only, ocean-only or in coupled mode. In each mode a run consists of an optional period of data assimilation followed by a prediction phase. Forecasts from a few hours to a few days ahead are required for numerical weather prediction while for climate modelling the prediction phase may be for tens, hundreds or even thousands of years. The choice of horizontal and vertical resolution is arbitrary and may be varied by the user. In practice, the resolution is constrained by the available computing power and a number of standard resolutions tend to be used. A separate reconfiguration module allows model data to be optionally interpolated to a new grid or area prior to the start of a run.

Application	Resolution	Grid	Levels
		E-W x N-S	
Climate Modelling	5.00° x 7.50°	48 x 37	19
Climate Modelling	2.50° x 3.75°	96 x 73	19
Middle Atmosphere	2.50° x 3.75°	96 x 73	42
Weather Forecasting	1.25° x 0.83°	288 x 217	19
Weather Forecasting	0.83° x 0.56°	432 x 325	30

Fig 1: *Global atmospheric configurations of the Unified Model used for production and research at the Met Office.*

A range of ancillary data may be incorporated into the model as a run progresses. The options range

from lateral boundary forcing information for regional configurations to the periodic updating of fields such as ozone concentration to allow for the effects of seasonal variations.

Prognostic, diagnostic and derived fields of data may be output on a time-step by time-step basis for inspection and further analysis, or as forcing information for sub-models such as a sea-state prediction model.

The wide range of options available within the Unified Model system means that a large number of parameters need to be set in order to specify and control a particular model configuration. A user-friendly X-Windows based user interface has been developed to make this task much easier. By use of interactive windows, a user may control parameters such as model resolution, the date and time of the initial data, the length of forecast, the choice of output diagnostics and so on. The user may also control the scientific content of the model by selecting from a library of alternative representations of the physical processes.

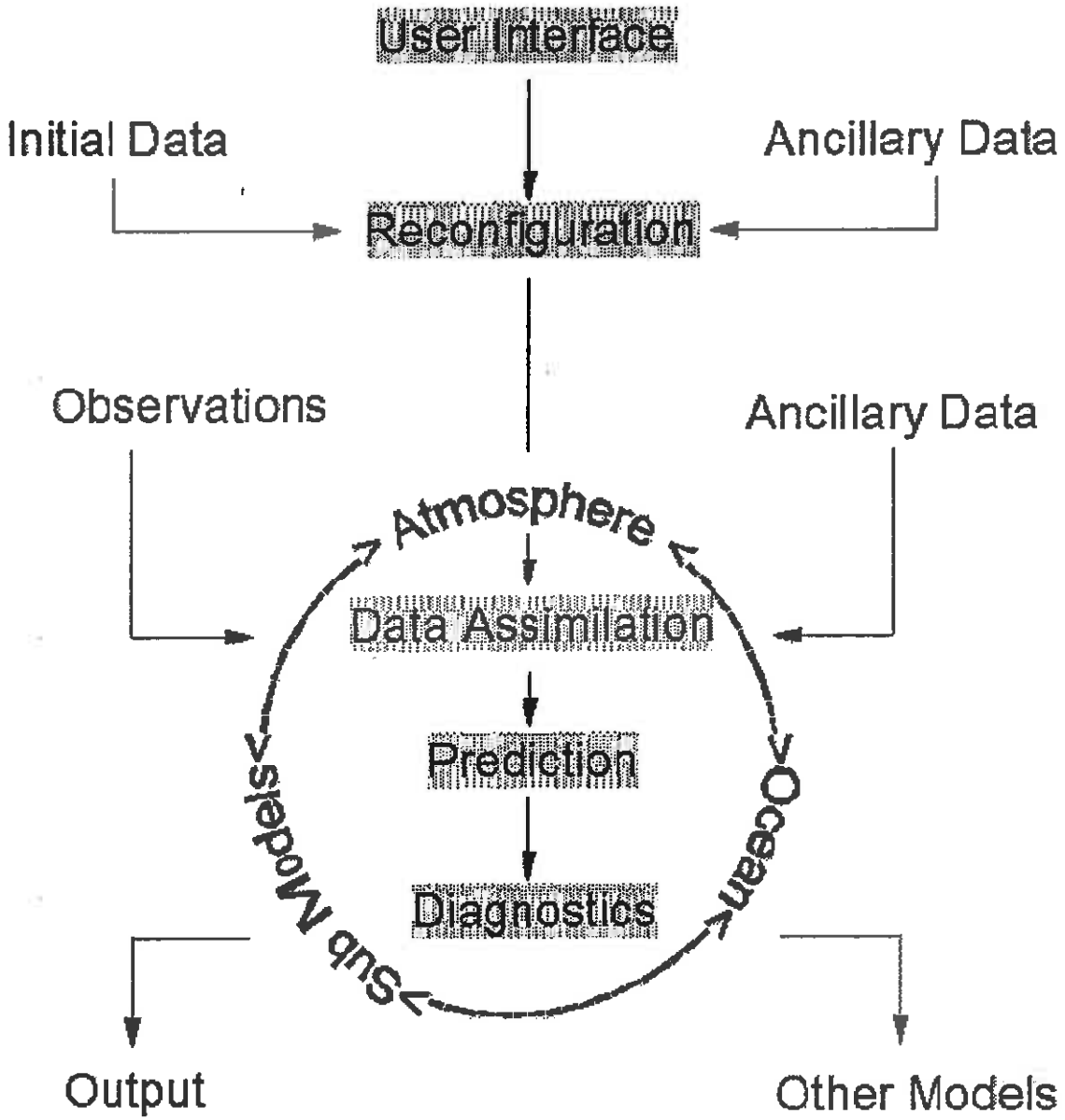


Fig 2: *The main components of the Unified Model system.*

2. Formulation

The main atmospheric and oceanic components of the model are described below. In addition to these, a number of external sub-models may be linked into the system. These include models of the sea-state, sea-ice and atmospheric chemistry.

2.1 Atmospheric Prediction

The atmospheric prediction component uses a set of equations that describe the time-evolution of the atmosphere. The equations are solved for a gas or fluid on a rotating, almost-spherical planet, the main variables being the zonal and meridional components of the horizontal wind, potential temperature and specific humidity. To solve the system of equations, a number of approximations or assumptions have to be made. In common with most other atmospheric models the Unified Model's atmospheric prediction scheme is based on the so-called hydrostatic primitive equations. This means that the model atmosphere is always in hydrostatic bálance and therefore there are no vertical accelerations. Most other atmospheric models also make the shallow-atmosphere approximation which derives its name from the fact that the depth of the atmosphere is much smaller than the radius of the Earth. The Unified Model does not make this assumption. This makes the equations a little more complicated to solve by adding in extra terms which can be important when planetary-scale motions are considered.

The equations can be solved in a variety of different ways. The Unified Model uses a grid-point scheme on a regular latitude-longitude grid in the horizontal and a hybrid vertical grid, which is terrain-following near the surface but evolving to constant pressure surfaces higher up. An efficient split-explicit scheme is used to solve the equations which is designed to conserve mass, mass-weighted potential temperature and moisture and angular momentum. These are important to ensure the integrity of the solutions for long integrations required for climate-change experiments.

Lateral boundary values may be output from larger scale integrations to support the running of regional models. Regional configurations of the model use a rotated latitude- longitude grid which ensures a quasi-uniform grid length over the whole integration domain.

The physical processes represented include:

- Atmospheric radiation allowing for the effects of clouds, water vapour, ozone, carbon dioxide and a number of trace gases.
- Land surface processes including a multi-layer soil temperature and moisture prediction scheme.
- A treatment of the form drag due to the sub-grid scale variations in orography.
- Vertical turbulent transport within the boundary layer.
- Large-scale precipitation determined from the water or ice content of a cloud.
- The effects of convection through a scheme based on the initial buoyancy flux of a parcel. It includes entrainment, detrainment and the evaporation of falling precipitation. An explicit treatment of downdraughts is included.
- The effects of the drag caused by vertically propagating gravity waves is modelled using sub-grid scale orographic variance and known absorption properties of gravity waves.

2.2 Oceanic Prediction

Ocean processes are represented by an ocean model that has been derived from that originally developed at the Geophysical Fluid Dynamics Laboratory, Princeton, USA. This is based on a finite difference representation that uses a spherical coordinate system in the horizontal and geometric depth as the vertical coordinate. It solves equations for the motion of the ocean that are similar to those used in the atmospheric component. The main variables used by the ocean model are: currents, potential temperature and salinity. In addition to the dynamical processes, the model includes representations of the following physical processes:

- Mixing in the upper ocean.
- Heating and cooling by surface fluxes, some of which can penetrate below the surface.
- Diffusion along isopycnal surfaces.

Ocean properties evolve over many centuries, so the model includes modifications to the equations of motion that allow it to run for long periods to attain equilibrium solutions.

Biological and chemical processes are important on the longer timescales used in climate modelling. The ocean model contains representations of biological life cycles and their effects on the carbon budget of the ocean.

Sea ice has a major impact on the climate of both the atmosphere and ocean. Within the ocean model there are several options for simulating sea ice, ranging from a scheme that assumes the ice to be stationary through to one in which the ice moves in response to winds, currents and the internal stresses of the ice.

2.3 Data Assimilation

Atmospheric and oceanic data assimilation is performed using an analysis correction scheme. This is an iterative analysis, with each variable being analyzed in turn. Appropriate constraints are included so as to improve balance and speed of convergence. In the atmosphere these include hydrostatic temperature increments derived from the analyzed surface pressure increments; geostrophic wind increments derived from the analyzed mass increments; and surface pressure and temperature increments derived from the analyzed wind increments using a linear balance relationship. Each iteration is interleaved with a timestep of the full forecast model to keep the analysis close to the preferred model solution. Observations are introduced into this continuous assimilation over a period around their validity time, with a peak weighting at their validity time. The extent of horizontal data spreading is determined by a continuous background error correlation function which has a time dependence such that progressively smaller scales are fitted.

3. Applications

The model is used by the Met Office for operational numerical weather prediction and by the Hadley Centre for Climate Prediction and Research to simulate and predict the Earth's climate. The model is also used by a number of meteorological centres and research organisations worldwide.

3.1 Numerical Weather Prediction

The Unified Model is used operationally at the Met Office to provide numerical forecasts of the atmospheric state for periods of a few hours to several days ahead. Both global and regional configurations are used, with the larger scale model providing lateral boundary values for higher resolution regional models. Several runs are made throughout each day against a fixed schedule and tight deadlines.

A number of major improvements to the scientific formulation of the Unified Model have been made during its lifetime. These have led to significant gains in the quality of operational forecasts.

Fig 3: *The skill of Met Office operational global forecasts as measured by the NAO index. The index increases as the skill of the forecasts improves. It is based on a scaled, weighted average of the root mean square errors of a range of key forecast fields. The Unified Model was introduced into operational service in June 1991.*

Limited area, regional configurations of the Unified Model are used to provide detailed guidance of the weather in the region of the United Kingdom.

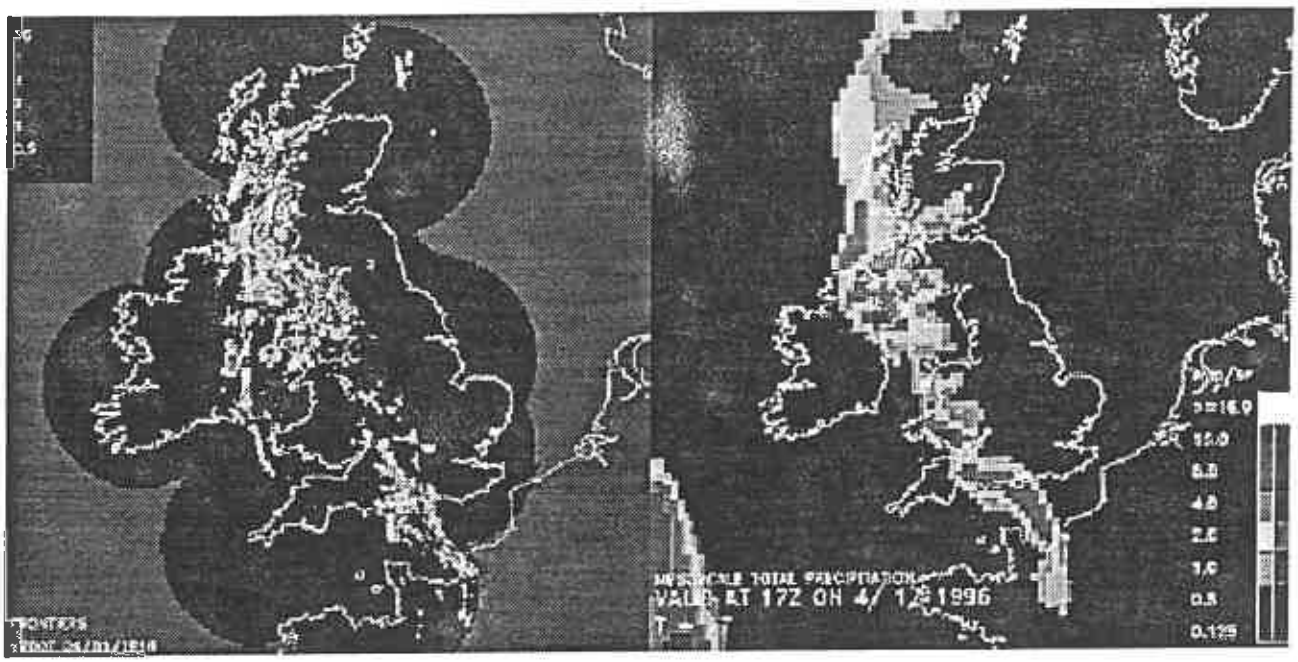


Fig 4: *A 12 hour forecast of precipitation intensity obtained using a high resolution (17Km) regional configuration of the Unified Model (right). The observed precipitation as measured by the UK radar network is also shown (left).*

3.2 Oceanographic Forecasting

FOAM, the Forecasting Ocean Atmosphere Model, is being developed to produce analyses and short-range forecasts of the ocean's temperature and salinity structure. It is based on the oceanic component of the Unified Model and is driven by surface fluxes of heat, fresh water, and momentum that are calculated from operational runs of the atmospheric component of the Unified Model.

Because FOAM is intended for short-range integrations, the oceanic initial state is very important. The success of FOAM is therefore very dependent on the quality of the Unified Model's data assimilation scheme.

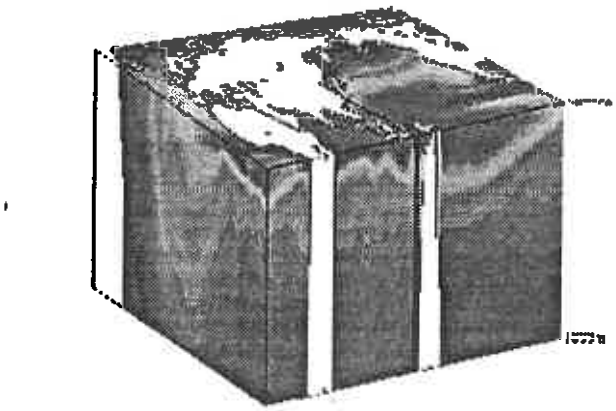


Fig 5: *The ocean temperature structure as analysed by FOAM.*

3.3 Climate Prediction

The prospect of climate change due to man's activities is a high profile scientific and political issue. The threat of global warming due to the steady increase in atmospheric concentrations of greenhouse gases has led to renewed efforts to understand the factors influencing the Earth's climate and to predict the extent and impact of climate change over the next century.

The Hadley Centre uses the Unified Model both to simulate the present climate in order to understand its natural variability and to predict global and regional climate change up to the end of the 21st century. Climate prediction requires models of the atmosphere, ocean, land surface and sea ice to be run in coupled mode so that the interactions between them are represented.

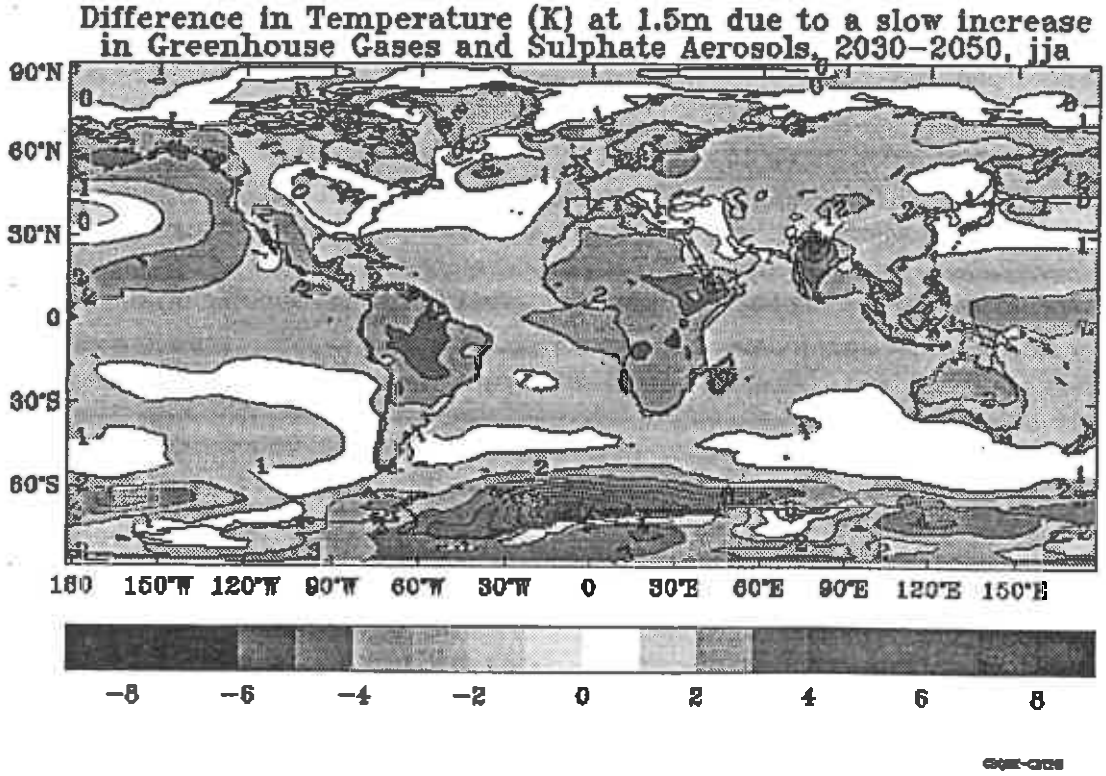


Fig 6: *A prediction of global temperature change.*

3.4 Middle Atmosphere Research

Daily analyses of the stratosphere are carried out at the Met Office using a version of the Unified Model's data assimilation scheme. The analyses are used in a variety of applications which are aimed at a better understanding of the dynamics and chemistry of the stratosphere. In particular, the analyses have proved invaluable in the interpretation of measurements from the Upper Atmosphere Research Satellite.

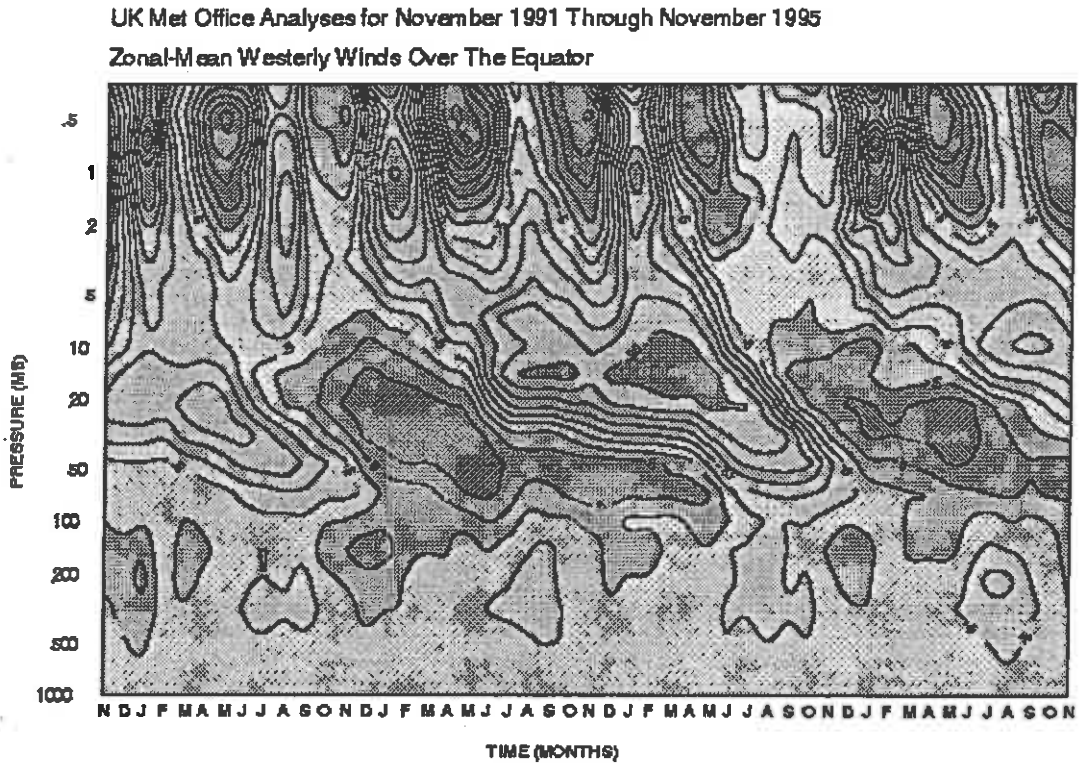


Fig 7: *Time series of winds over the equator, analysed using the stratospheric configuration of the Unified Model. The winds show a clear Quasi-Biennial Oscillation in the stratosphere and a Semi-Annual Oscillation near the stratopause.*

4. Features and Capabilities

4.1 User Interface

The Unified Model is a very flexible system allowing a vast number of choices. To help the user make the most of this flexibility, a graphical user interface, known as the UMUI (Unified Model User

Interface), has been developed. The UMUI is X-Windows based and runs in the familiar environment of the user's own local workstation. It is designed to give access to the full functionality of the Unified Model whilst speeding up the learning process.

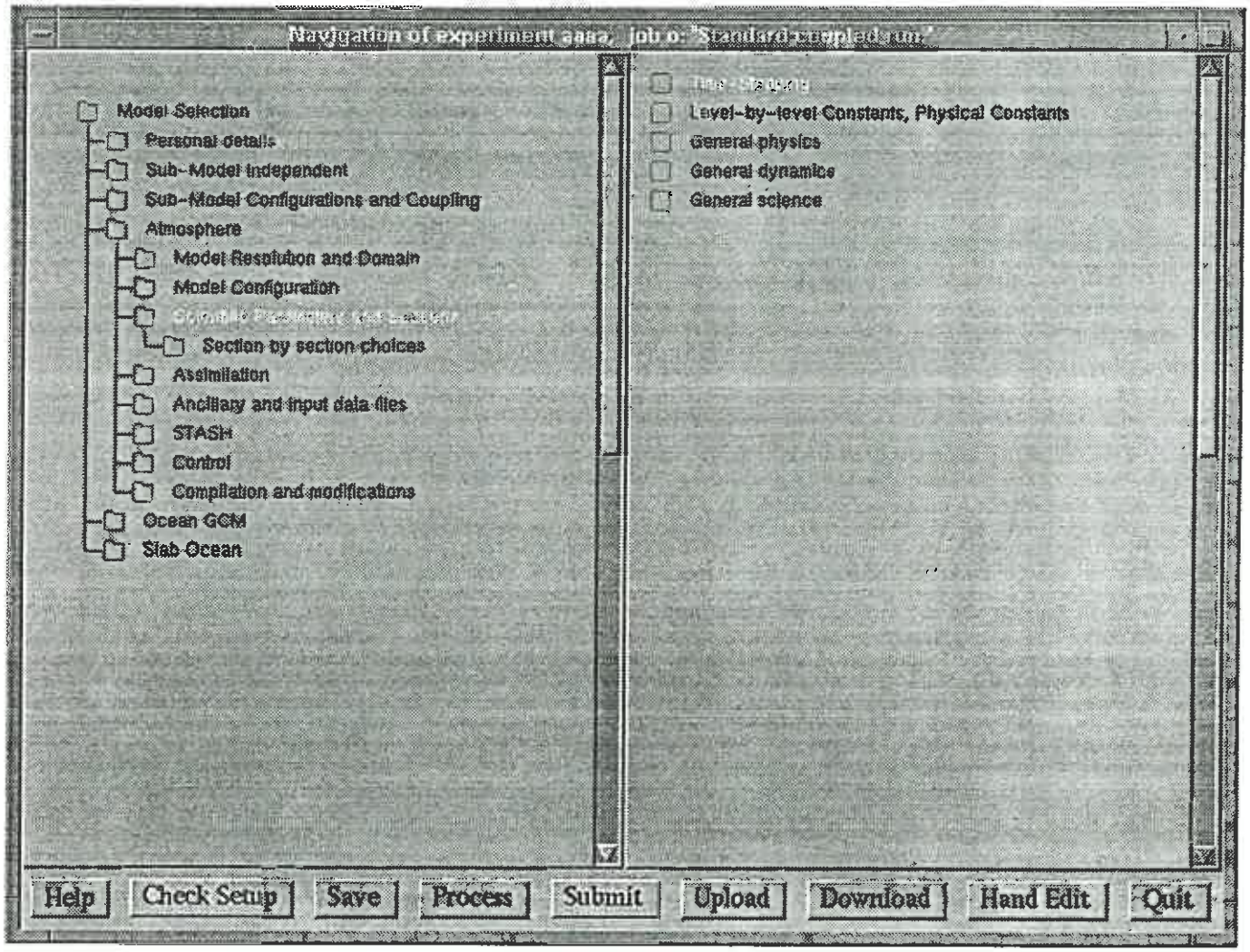


Fig 8: *The main navigation window of the UMUI. Nodes in the tree (left) may be expanded and collapsed. In this example, the atmospheric model node is expanded. Selected nodes are opened up to display windows (right).*

Using a central database that works in a distributed environment, the UMUI provides an efficient method of defining model runs and for managing those definitions. A run definition is known as a job. Users can search for and copy jobs belonging to colleagues, and definitions can even be sent by email from one site to another. This allows colleagues and collaborators at remote sites to increase their efficiency by pooling their effort and knowledge. The job management system also provides help for users wanting to upgrade from one version of the Unified Model to another.

In addition to the job management system, the UMUI contains a comprehensive job definition system. This is an intelligent editor that allows modifications to be made to existing jobs. It is made up of a large number of windows, each with visual clues to ensure that users can quickly see when options have been

disabled due to other responses. To further aid the user all windows have a help button that displays information relating to the options available on the window.

Once a job has been defined, the responses are translated into control files that can be read by the Unified Model. On request, the UMUI will then copy these to the target machine and submit the job. The control files are text based and so a user can easily over-ride the User Interface by editing the control files. This facilitates the prototyping of new facilities.

4.2 Reconfiguration

The reconfiguration module processes the model's initial data. It allows the horizontal or vertical resolution of the data to be changed or the creation of a limited area region. Ancillary data may also be incorporated into the initial data. Fields such as the specification of orography or the land-sea mask, for example, may be overwritten by more appropriate values if the horizontal resolution has been changed. Other facilities available within the reconfiguration module include the incorporation of ensemble perturbations, tracer fields and the transplanting of prognostic data.

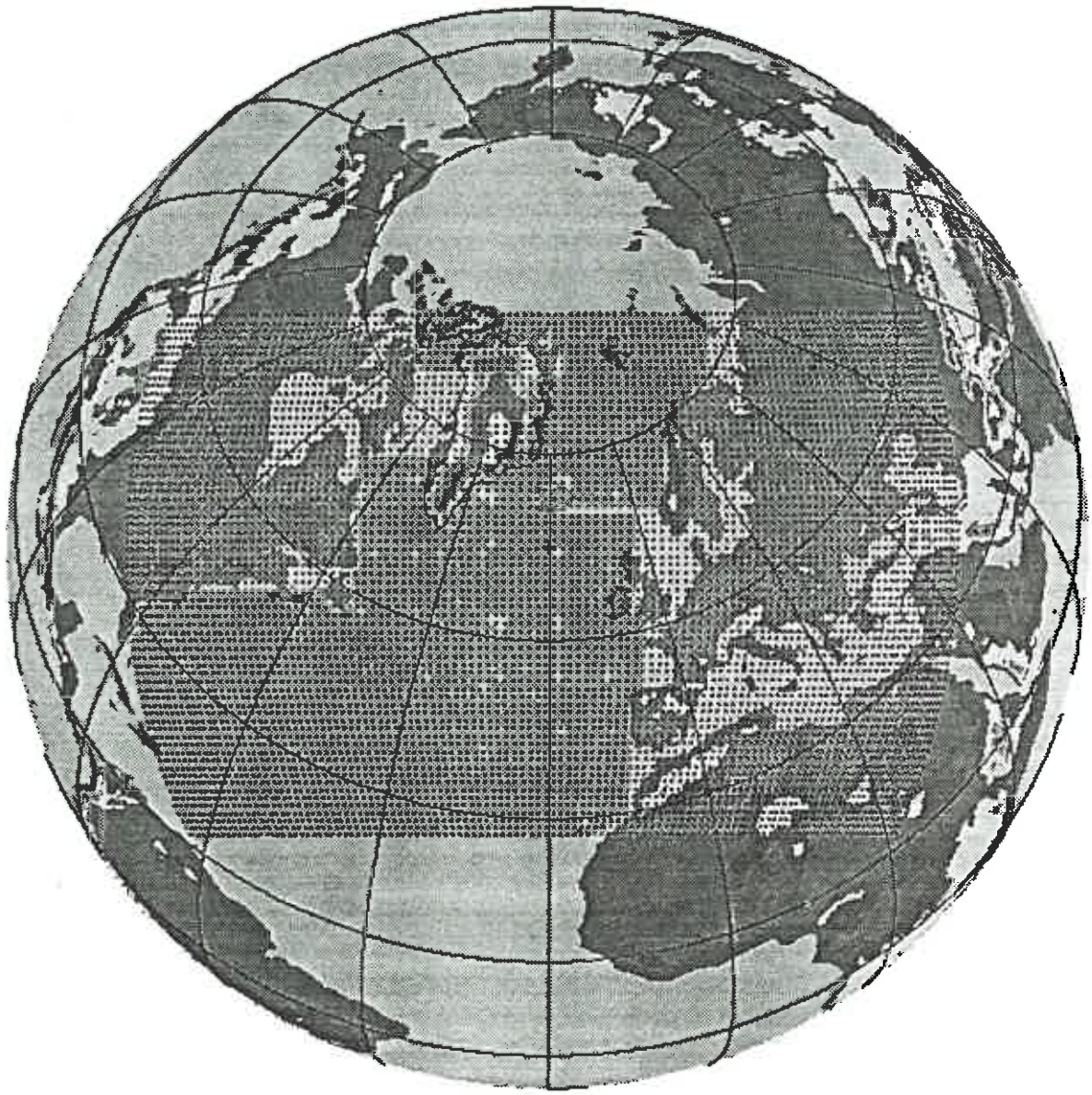


Fig 9: *A regional integration domain and grid. Initial data may be interpolated onto such domains via the reconfiguration module.*

4.3 Tracers

Both the atmospheric and oceanic components support the advection of passive tracers using a shape preserving advection scheme. The methods are designed to ensure that sharp gradients are preserved while keeping all concentrations greater than or equal to zero. This facility may be used to examine dispersion from point sources or as the basis for more involved chemical modelling by the addition of extra code. For example, atmospheric forecast configurations of the model include an aerosol variable which is advected using the tracer scheme, and may optionally have sources and sinks applied. This is

used to estimate visibility, and may be adjusted by the assimilation of visibility data.

4.4 Ancillary Data

New ancillary data may be incorporated as an integration proceeds to allow for the effects of seasonally varying quantities such as surface vegetation or snow cover. The choice of whether to include ancillary data will depend on the application. For example, the system supports daily updating of sea-surface temperatures based on climatological or analysed data - but this facility is not needed in coupled ocean-atmosphere runs of the model. In fact options exist to allow most boundary forcing variables to be predicted. However, it is often necessary to constrain such fields to observed or climatological values for reasons of computational economy or scientific expedience.

4.5 Diagnostic Processing

Diagnostic data output from the model may be varied on a timestep by timestep basis. Horizontal fields, sub-areas or timeseries may be be requested, along with the accumulation, time meaning or spatial meaning of prognostic fields. The output may also be split across a number of files in order to facilitate the separate post-processing of classes of diagnostics.

4.6 Output

The results of an integration are stored in a format compatible with other file types used within the Unified Model system. Several utilities exist which will convert them into a format suitable for further processing. These formats include GRIB - the WMO standard for storing fields of meteorological data in a machine independent format. Utilities to print out and compare the contents of Unified Model files are available. These, coupled with the bit reproducibility facility (see below), offer a powerful development and debugging aid.

4.7 Computer Requirements

The code is primarily written in FORTRAN 90 and runs under the Korn shell of the UNIX operating system. A small number of low-level service routines are written in ANSI C to facilitate portability. The model will normally require a powerful supercomputer for time critical production work. It is written to be efficient on either shared memory vector supercomputers or distributed memory massively parallel processing (MPP) computers and be bit reproducible independently of the number of processing elements used. The code may also be run on workstation systems using the IEEE standard for representing floating point numbers. Workstations are particularly suited to development work or research activities requiring the use of low resolution configurations of the model. A message passing version of the code is available for running on MPP computers and networks of workstations.

5. The Future

Improvements to the scientific formulation and software capabilities of the Unified Model are always being sought and considered. A number of important developments are planned for the next few years:

- Major changes to the atmospheric prediction scheme which involve less approximation and improved methods of solution are under development. The non-hydrostatic form of the governing equations will be adopted, enabling the model to be used for very high resolution forecasting.
- The Unified Model system will move towards the use of variational methods of data assimilation. In this, a model state is constructed that is the best statistical fit to the observed data. A system like this requires a method of blending the observations with the background field provided by a simple linerized model which is integrated forwards and backwards in time to fit the observations to an evolving model state.
- The software infrastructure will be enhanced to allow the flexible incorporation of a range of environmental sub-models into the Unified Model system.

Head of Numerical Modelling
The Met Office
London Rd
Bracknell
Berks
UK

March 1996

Part III
NUMERICAL WEATHER PREDICTION

NUMERICAL WEATHER PREDICTION

The production of a weather forecast by solving a set of mathematical equations on a computer

Characterised by:

- Time critical nature of the work
- Complexity of the equations
- Large volumes of data
- Use of very powerful computers

Notes: NWP

1. Where we are today and where we are going in the future
2. The equations describe the motion and thermodynamics of the atmosphere
3. The computational techniques are similar to those used in other scientific and engineering applications. Known as CFD. For example, aerospace, automobile and oil industries.
4. Collection of observations from around the world + 5 day fc takes < 4hrs
5. ~0.5 million lines of code
6. 10 million obervations per day
7. Order of a CRAY T3E recently announced - novel design - > 5 times current computer

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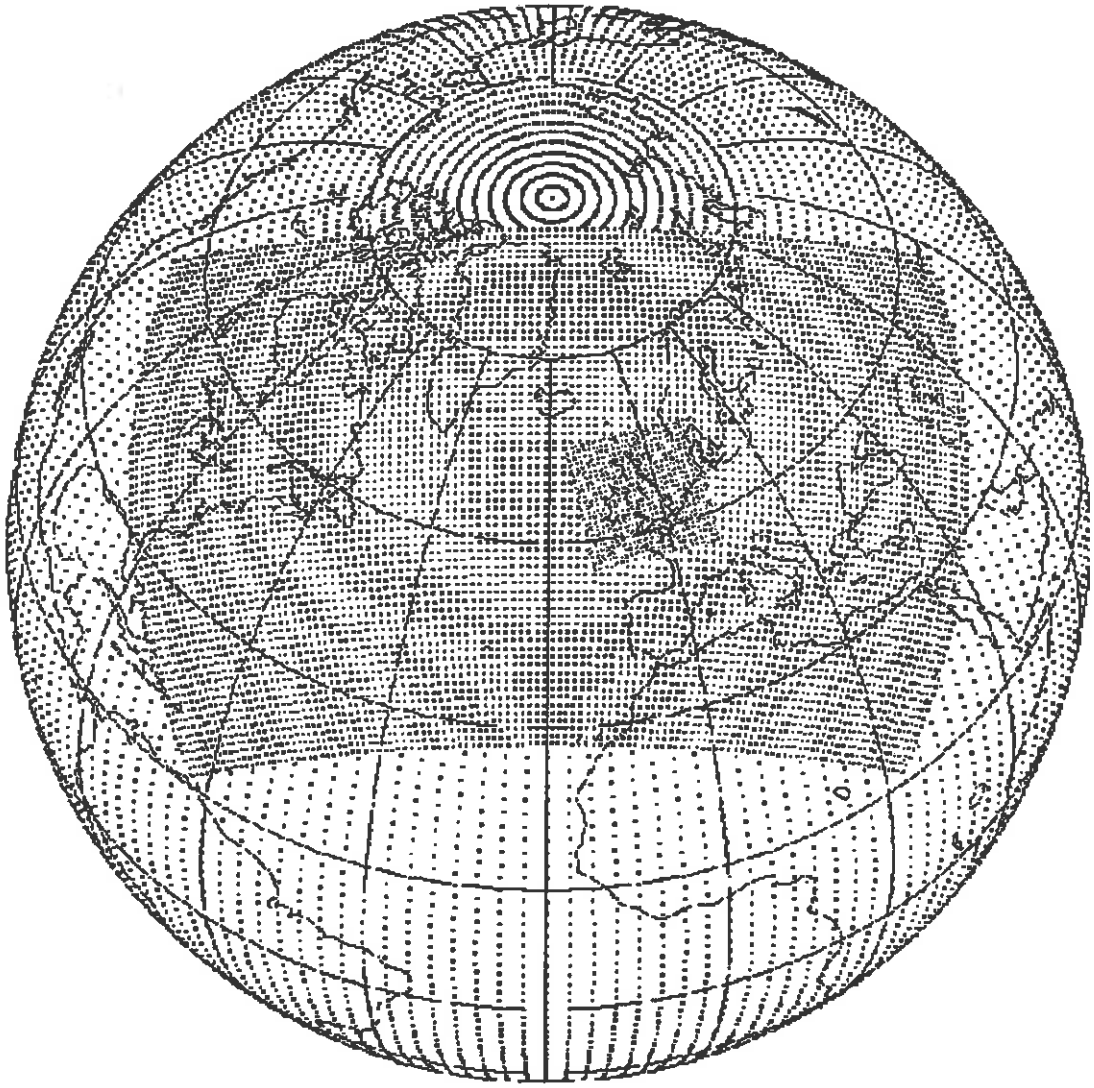
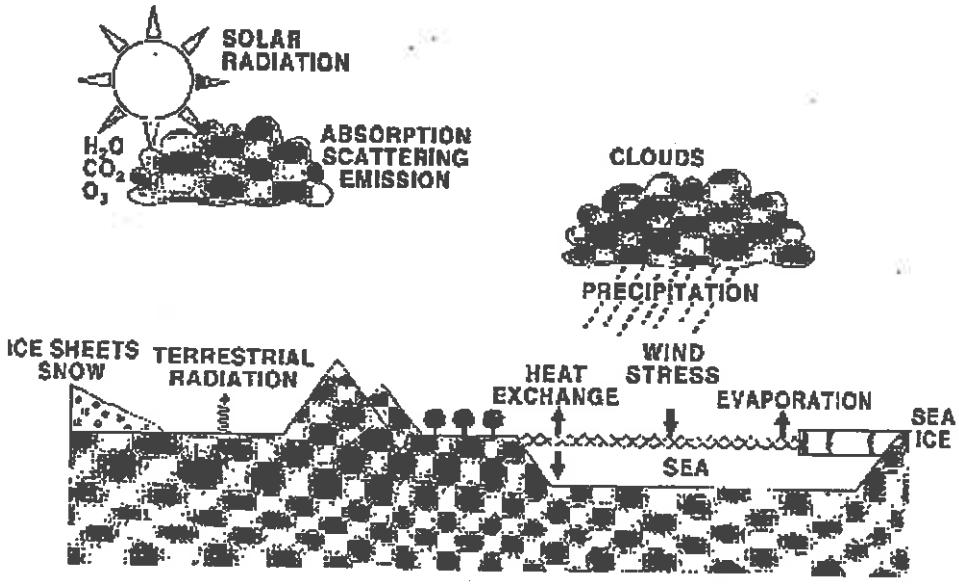
FORECAST MODELS - GRIDS AND AREAS



Notes: FORECAST MODELS

1. The equations are solved for a prescribed set of grid boxes that are distributed horizontally and vertically in the atmosphere
2. For every box at every (time) step we predict:
   - Wind
   - Temperature
   - Pressure
   - Humidity
3. The cost of solving the equations increases with the number of boxes and/or their reduction in size
4. Hence, limited - area models for more detailed weather forecasts
5. Use 3 nested models resolution from 90 --> 17 KM 19 --> 30 levels
6. Million grid boxes

PHYSICAL BASIS OF ATMOSPHERIC MODELLING



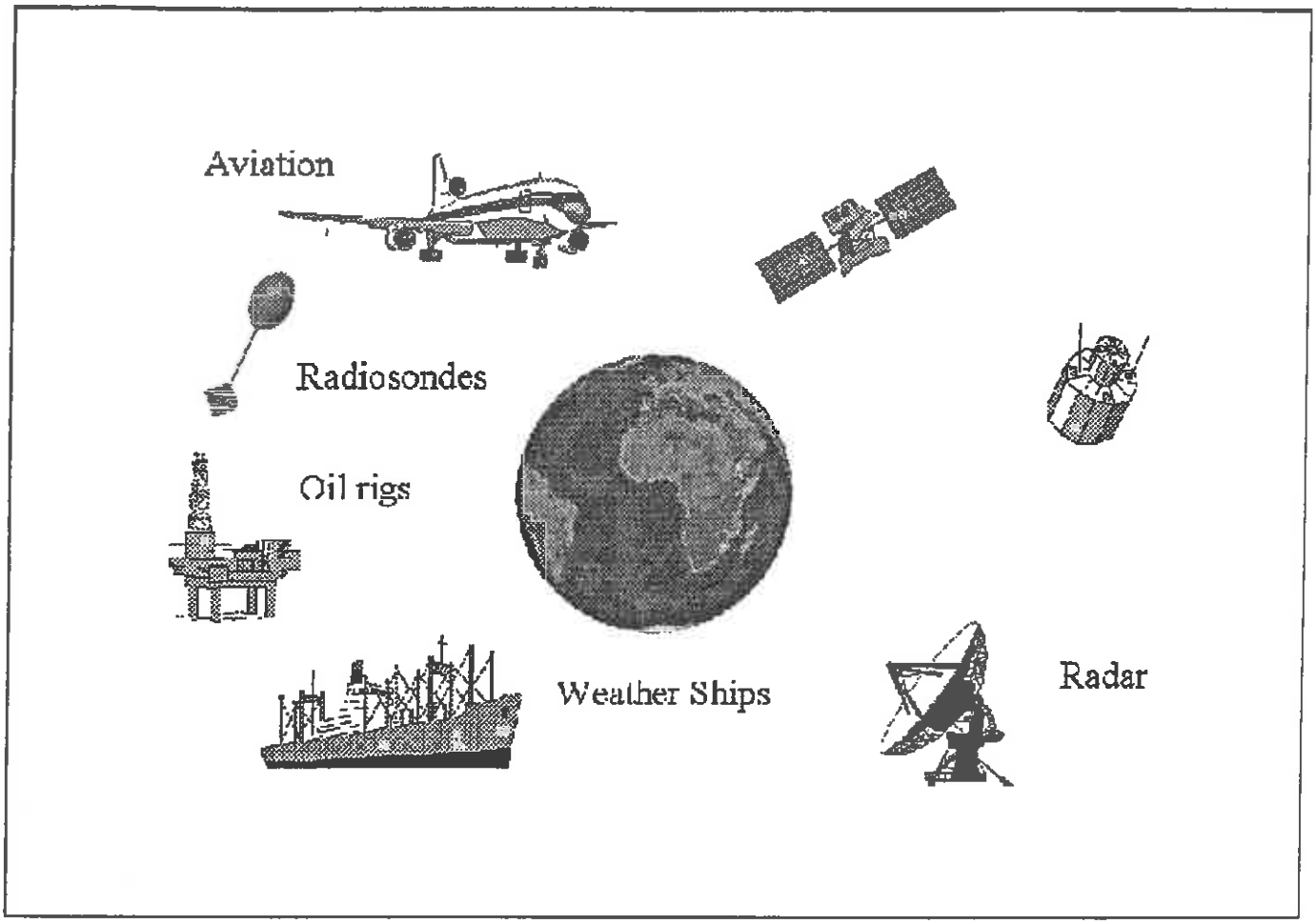
Notes:

In addition to the motion of the air we need to take into account:

- The Earth's surface (land/sea, mountains, vegetation/land type, friction)
- Solar radiation and clouds
- Rain and snowfall

The physical processes in general terms describe the weather. They account for approx 50% of the cost of a numerical forecast.

INITIAL CONDITIONS - GLOBAL OBSERVING SYSTEM



Notes:

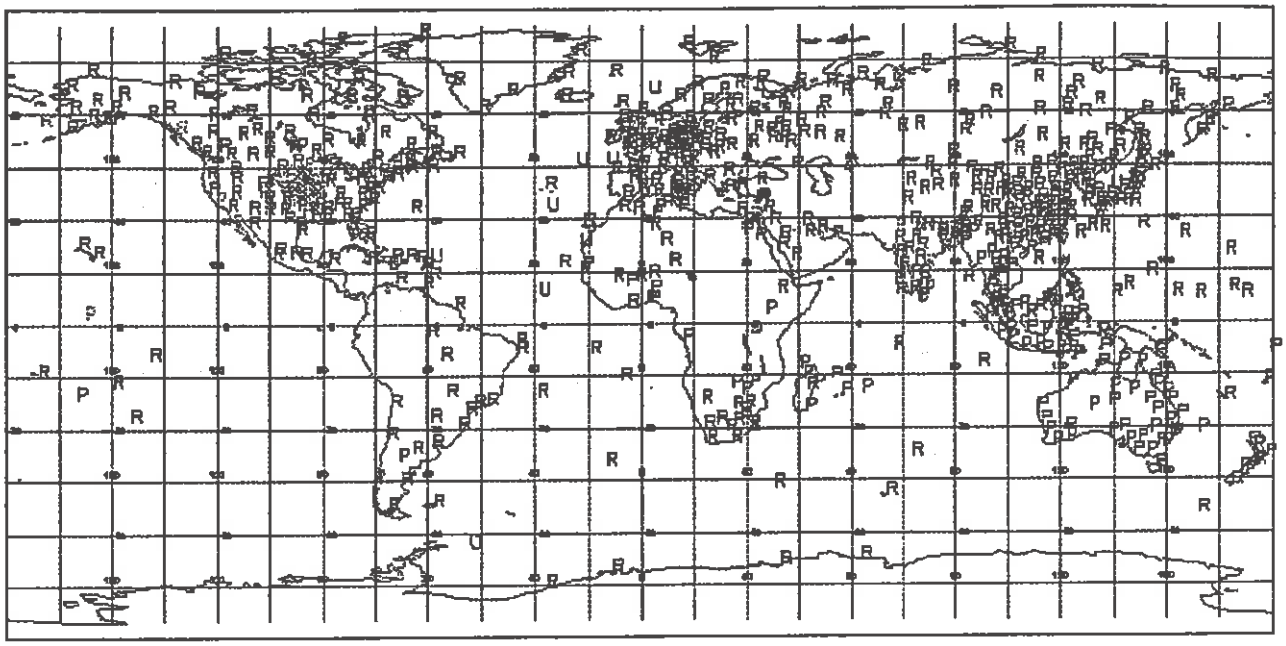
To start the forecast we need to specify the initial state of the atmosphere. A complete 3-D picture of the current state of te atmosphere.

We use many different types of observations

- Different coverage
- Different levels
- Different accuracy
- Different times

Gaps in the data coverage are filled by forecast data from the previous analysis time

RADIOSONDE OBSERVATIONS

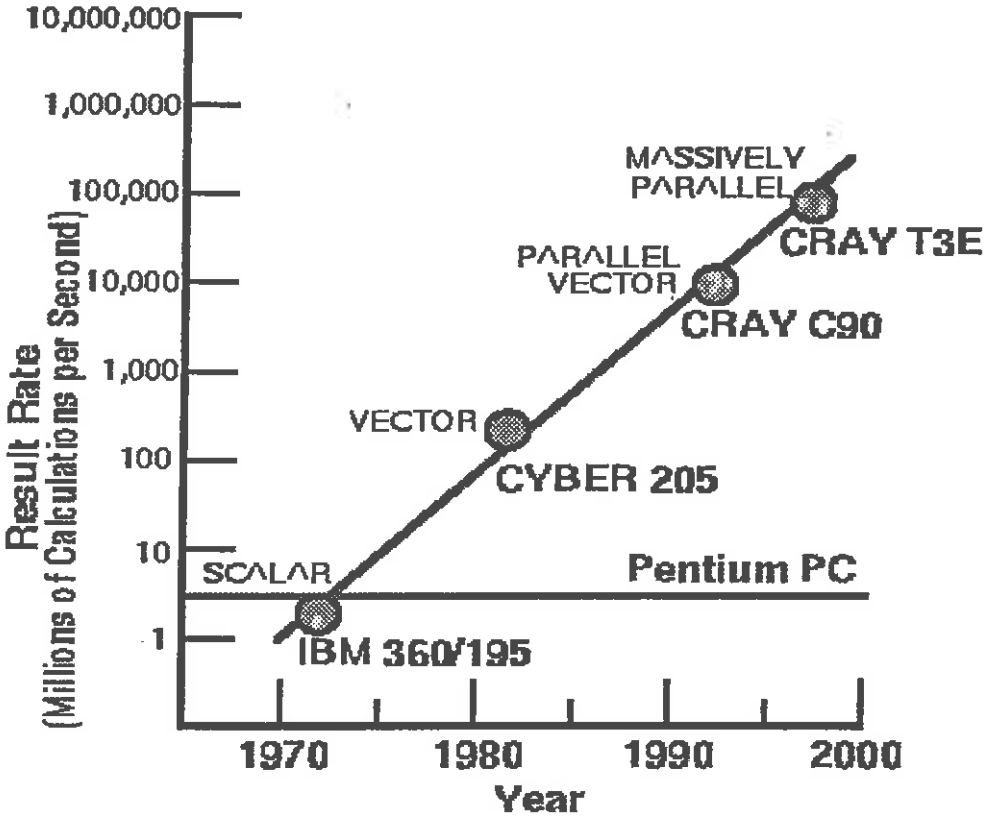


12319 OBS12319 PLOTTED
7821 R TEMP 4315 P PILOT 183 U TSHIP

Notes: OBSERVATIONS

1. Data coverage is incomplete and the initial state is not fully determined
2. Radiosodes give the most detailed picture of the vertical structure of the atmosphere. (The 3-D picture).
3. Distributed near the main population centres
4. Aircraft fly between the main population centres
5. Satellites give more complete coverage, but less detail

Performance of Met. Office Supercomputers



Date	Machine	Resolution Global/UK	Millions of Boxes
1972	IBM 360/195	300/100 Km	0.03
1982	CYBER 205	150/75 Km	0.4
1991	CRAY C90	90/17 Km	1.2
1997	CRAY T3E	60/12 Km	5

Notes: COMPUTER POWER

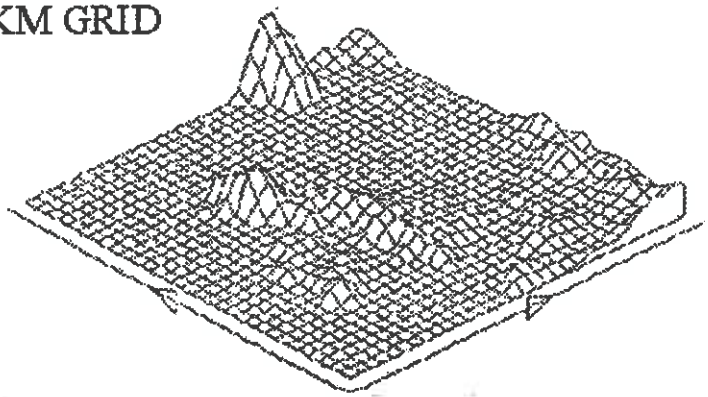
1. The increase in accuracy of weather forecasts has progessed in step with the available computer power

   Use of "supercomputers" has allowed

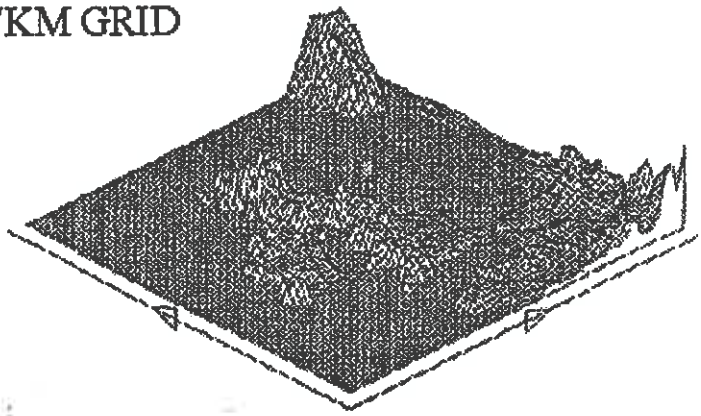
   - Increases in the number of grid boxes or a reduction in their size
   - Improved representation of physical processes
   - The introduction of better mathematical and numerical techniques for both modelling and analysis
2. The CRAY T3E represents the latest in a series of computers. It is a massively parallel computer. The Met Office system will have over 600 processors. The C90 has 16.
3. By 2005 computers will be 10 - 100 times more powerful. Use 5KM grid over UK.

OROGRAPHY

50KM GRID



17KM GRID

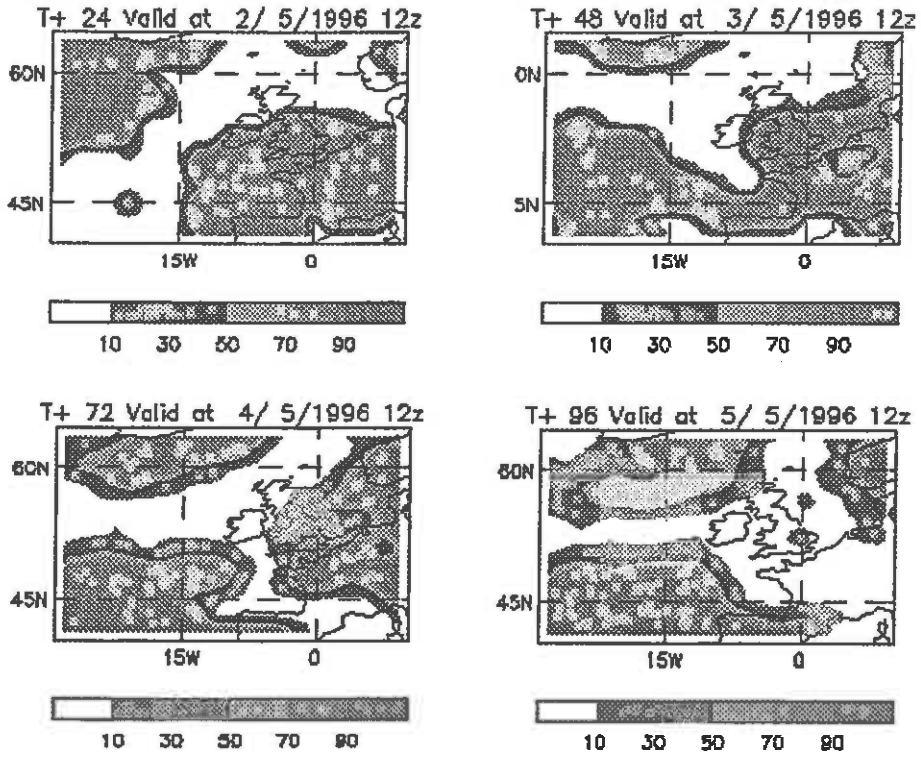


Notes: MORE DETAIL

1. Increases in computer power mean we can represent the important physical processes in more detail
2. Use orography to illustrate
3. Resolve hills and valleys in more detail
4. Cheshire gap - showers in NW airstream
5. North and South Downs - Showers from the south
6. Improved fog and precipitation forecasts

7

Probability of precipitation



Notes: FORECAST UNCERTAINTY

1. The forecast equations exhibit chaotic behaviour
2. Small differences in initial conditions may lead to large differences in solution after several days
3. Use ensembles of forecasts to deal with this uncertainty
4. Run tens or hundreds of forecasts from slightly different initial conditions
5. Generate probability forecasts
6. This is an example of a fc of precipitation for 1,2,3 & 4 days ahead.

8

THE FUTURE

Weather forecasts will improve further over the next decade

- A 3 day forecast will have the same level of skill as a 2 day forecast today
- Forecasts will provide more detailed predictions of weather conditions
- Probabilities will be used to express forecast uncertainty

For more information browse:

http://www.meto.gov.uk/sec5/sec5pg2.html

1. Down to 5Km over the UK
2. Scattered showers or periods of rain.
3. Improve the representation of physical processes
4. Make better use of observations
5. Improve mathematical and numerical techniques
6. Reduce the size of grid boxes
7. Use ensemble techniques to deal with forecast uncertainty
8. Automate more of the forecast process

HAND OVER TO JOHN FOOT FROM THE MET RESEARCH FLIGHT

Part IV

PROGRESS REPORT ON THE GLOBAL DATA PROCESSING SYSTEM 1996

PROGRESS REPORT ON THE GLOBAL DATA PROCESSING SYSTEM 1996

UNITED KINGDOM

METEOROLOGICAL OFFICE (BRACKNELL)

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1. HIGHLIGHTS OF THE YEAR

1.1 Forecast models

The main changes to the versions of the Unified Model in the suite for numerical weather prediction were the following:

Jan 16 - Several physics routines were revised in all versions of the model, including:

- a change in the formulation of mixed cloud;
- a correction to saturation vapour pressure;
- a revised parametrisation for the radius of water drops;
- small modifications to the precipitation scheme.

May 21 - Regular weekly updating of the soil moisture content in the UK Mesoscale Model was introduced.

Jul 23 - The resolution of the file that specifies the 'land use' in the UK Mesoscale Model was increased from 1 degree to 10 minutes.

Nov 5 - The following changes were implemented in the Global Model:

- the advection scheme was changed from 2nd order to 4th order;
- the convection scheme was enhanced to include convective momentum transports;
- revisions were made to the Gravity Wave Drag parametrisation scheme.

The main changes to the wave models in the suite were as follows:

Jan 16 - The global wave model was extended to run to T+144.

Sep 10 - Additional points were added to global forecast spectral output.

The main change to the Nowcasting model was as follows:

Dec 18 - The cloud analysis and forecast scheme was implemented on the Nimrod system. This generates hourly analyses and forecasts of 3-D cloud structure for the UK and surrounding waters for the period T+0 to T+6 hours.

1.2 Observations, quality control and assimilation

The main changes to the use of observations were the following:

Apr 16 - Temperature information in global TOVS radiances assimilated into the Global Model using a 1DVAR technique through the new GLOSS (GLObal Sounding System).

Apr 16 - 'Latent Heat Nudging' was added into the assimilation for the UK Mesoscale Model.

Apr 27 - Infra-red winds from GOES-9 were introduced into the model (replacing GOES-7 data).

Apr 29 - The global wave model switched to assimilating ERS-2 altimeter data (from ERS-1).

Jul 23 - The Moisture Observation Pre-processing System (MOPS) was introduced into the Regional Model assimilation.

Nov 5 - Humidity information from global TOVS radiances assimilated into the Global Model via GLOSS.

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2. EQUIPMENT IN USE

	A) Front end mainframe computer	B) Supercomputer
2.1	Make and model of computer	
	A) IBM 9672 - R73	B) Cray C916/16
2.2	Main Storage	
	A) 2 Gbytes	B) 2 Gbytes memory 4 Gbytes solid state device
2.3	Operating system	
	A) MVS/ESA Version 5.2.2	B) UNICOS Version 8.0.4.2
2.4	External input/output devices	
	A) 294 Gbytes DASD 1 Gbyte semi-conductor disk 4 reel tape drives 300 terminals, VDUs, etc. 20 local printers 2 line printers 2 microfiche recorders	B) 12 DA62 Disk Array Units 4 DD62 Disk Units (total 140 Gbytes) HIPPI link to Cray EL98

28 magnetic cartridge drives connected
to a GRAU automated tape library system
with a capacity of 28,800 cartridges.
Connectivity to both the 9672 and the C90.

2.5 Plotters and line drawers

A) 1 inclined flat-bed Calcomp plotter B) -

3. DATA AND PRODUCTS USED FROM THE GTS

3.1 Observations

The data assimilation system makes use of the following observation types:

Data type	*No. per day*	*Data used & corrections made*
SYNOP	18500	Pressure from group 4 or group 3.
SHIP	3300	Pressure and wind; some pressures corrected.
DRIFTER	4000	Pressure.
TEMP/ PILOT	1930	Temperature, wind and humidity at standard and special levels. Temperature corrections applied; observations vertically averaged over model layers before being presented to analysis. Wind at standard and special levels. Vertical averaging as with TEMPs.
AIREP	3600	Wind and temperature.
AMDAR/ ASDAR	15000	Wind and temperature.
SATOB	14500	Wind. Low-level data over land outside tropics not used.
120km BUFR TOVS	55000	Clear column brightness temperatures assimilated via GLOSS
ERS-2 scatt. winds	180000	Near-surface wind.

3.2 Gridded products

Products from WMC Washington are used as backup in the event of a systems failure (see section 7.2.3). The WAFS Thinned GRIB products at an effective resolution of 140km (1.25 x 1.25 degrees at the equator) are received over cable in 6 hour intervals out to T+72. Since October 1996 we have also

been receiving these products over the ISCS satellite link. Fields in this format include geopotential height, temperature, relative humidity, horizontal and vertical components of wind on most of the standard pressure levels, rainfall, PMSL and absolute vorticity.

Products received from Paris and from ECMWF (including Ensemble Prediction System forecasts) are used internally for national forecasting.

4. DATA INPUT SYSTEM

Fully automated.

5. QUALITY CONTROL SYSTEM

5.1 Quality control of data prior to transmission on the GTS

Both manual and automatic checks are performed in real-time for surface and upper-air data from the UK, Ireland, Netherlands, Greenland and Iceland. Checks are made for missing or late bulletins or observations, and incorrect telecommunications format. Obvious errors in an Abbreviated Heading Line or in the syntax of a message are corrected before transmission onto the GTS.

5.2 Quality control of data prior to use in numerical weather prediction

All observations used in NWP pass through the following quality-control steps:

1. Checks on the code format. These include identification of unintelligible code, and checks to ensure that the identifier, latitude, longitude and observation time all take possible values.
2. Checks for internal consistency. These include checks for impossible wind directions, excessive wind speeds, excessive wind shear (TEMP/PILOT), a hydrostatic check (TEMP), identification of inconsistency between different parts of the report (TEMP/PILOT), and a land/sea check (marine reports).
3. Checks on temporal consistency on observations from one source. These include identification of inconsistency between pressure and pressure tendency (surface reports), and a movement check (SHIP/DRIFTER).
4. Checks against the model background values. The background is a T+6 forecast in the case of the global model and a T+3 forecast in the case of the regional or mesoscale model. The check takes into account an assumed observation error, which may vary according to the source of the observation, and an assumed background error, which is redefined every six hours using a formulation that includes a synoptic-dependent component.
5. Buddy checks. Checks are performed sequentially between pairs of neighbouring observations. These checks are only performed on some observation types.

Failure at step 1 is fatal, and the report will not be used. The results of all the remaining checks are

combined using Bayesian probability methods (Lorenc and Hammon, 1988). Observations are assumed to have either normal (Gaussian) errors, or gross errors. The probability of gross error is updated at each step of the quality control, and where the final probability exceeds 50 per cent the observation is flagged and excluded from use in the data assimilation.

6. MONITORING OF THE OBSERVING SYSTEM

Non-real-time monitoring of the global observing system includes:

1. Automatic checking of missing and late bulletins.
2. Three-monthly monitoring checks on the transmission and reception of data.
3. Annual monitoring checks on the transmission and reception of global data under WMO data-monitoring arrangements.
4. Monitoring of the quality of marine surface data as lead centre designated by CBS. This includes the provision of monthly and near-real-time reports to national focal points, and 6-monthly reports to WMO (available on request from Meteorological Office, Bracknell).
5. Monitoring the quality of other data types and the provision of reports to other lead centres or national focal points.

7. FORECASTING SYSTEM

The forecasting system consists of:

1. Global atmospheric data assimilation system
2. Global atmospheric forecast model
3. Regional atmospheric data assimilation system
4. Regional atmospheric forecast model
5. Mesoscale atmospheric data assimilation system
6. Mesoscale atmospheric forecast model
7. Transport and dispersion model
8. Nowcasting model
9. Global wave hindcast and assimilation/forecast system
10. Regional wave hindcast and forecast system
11. Regional model for sea-surge.

The global atmospheric model provides lateral boundary conditions for the regional atmospheric model and surface boundary conditions for the global wave model. The mesoscale model is run four times a day using lateral boundary conditions provided by the regional atmospheric model. The global wave model system includes the assimilation of wave height and wind speed observations from the altimeter on ERS-2. The global wave model provides lateral boundary conditions for the regional wave model, and the regional atmospheric model provides the surface boundary conditions. The nuclear accident model is run when needed.

7.1 System run schedule

Run	Model	Data assimilation	Hindcast	Forecast	Cut-off	Product available	Boundary values
L00	Regional Atmosphere	2230-0130	-	T+36	0155	0220	G12
W00	Regional wave	-	12-00	T+36	0155	0225	L15,L18, L21,L00
M00	Mesoscale Atmosphere	2230-0130		T+18	0230	0300	L00
G00	Global Atmosphere	2100-0300	-	T+144	0305	0405	-
W00	Global wave	-	12-00	T+120	0305	0420	G18,G00
L03	Regional Atmosphere	0130-0430	-	T+6	0450	-	G00
M03	Mesoscale Atmosphere	0130-0430	-	T+3	0735	-	L03
L06	Regional Atmosphere	0430-0730	-	T+36	0755	0820	G00
M06	Mesoscale Atmosphere	0430-0730	-	T+30	0830	0915	L06
U00	Global Atmosphere	2100-0300	-	T+9	1120	-	-
G06	Global Atmosphere	0300-0900	-	T+9	1200	-	-
SST	SST Analysis	0000-0000	-	-	1200	-	-
V06	Regional Atmosphere	0430-0730	-	T+6	1230	-	G00
L09	Regional Atmosphere	0730-1030	-	T+6	1245	-	G00
M09	Mesoscale Atmosphere	0730-1030		T+3	1300		L09
L12	Regional Atmosphere	1030-1330	-	T+36	1355	1420	G00
W12	Regional wave	-	00-12	T+36	1355	1425	L03,L06,L09,L12
M12	Mesoscale Atmosphere	1030-1330	-	T+24	1430	1500	L12
G12	Global Atmosphere	0900-1500	-	T+144	1505	1605	-
W12	Global wave	-	00-12	T+120	1505	1620	G06,G12
L15	Regional Atmosphere	1330-1630	-	T+6	2000	-	G12

L18	Regional Atmosphere	1630-1930	-	T+36	2020	2040	G12
M15	Mesoscale Atmosphere	1330-1630	-	T+3	2110	2155	L15
M18	Mesoscale Atmosphere	1630-1930	-	T+18	2125	2210	L18
U12	Global Atmosphere	0900-1500	-	T+9	2320	-	-
G18	Global Atmosphere	1500-2100	-	T+9	0000	-	-
V18	Regional Atmosphere	1630-1930	-	T+6	0030	-	G12
L21	Regional Atmosphere	1930-2230	-	T+6	0045	-	G12
M21	Mesoscale Atmosphere	1930-2230	-	T+3	0100	-	L21

7.2 Global forecasting system

7.2.1 Data assimilation

Analysed variables	Wind components, potential temperature, relative humidity, surface pressure.
Analysis domain	Global.
Horizontal grid	Spherical latitude-longitude with poles at 90°N and 90°S. Resolution: 0.83° latitude, and 1.25° longitude. Variables staggered on Arakawa B-grid.
Vertical grid	19 levels, hybrid co-ordinates (eta = A/p_0 +B);
	layer boundaries at 1.0, 0.994, 0.956, 0.905, 0.835, 0.75, 0.65, 0.55, 0.46, 0.385, 0.325, 0.275, 0.225, 0.175, 0.125, 0.075, 0.04, 0.02, 0.01, 0.0005;
	levels are (assuming surface pressure of 1000 hPa): 997, 975, 930, 870, 792, 700, 600, 505, 422, 355, 300, 250, 200, 150, 99, 57, 30, 15, 4.6 hPa.
Interpolation method	Based on successive correction scheme.
Assimilation method	Data grouped into 6-hour time windows centred on analysis hour for quality control. Model values repeatedly corrected by interpolated data during integration leading up to and beyond the analysis time (Lorenc et al., 1991). Maximum weights assigned to data at their observation time. Balanced increments are included from both analysed temperature increments and analysed wind increments.
Assimilation model	As global forecast model (see 7.2.2) but with divergence damping of 1.0 x 10^6 m^2s^{-1} included.
Assimilation cycle	Data assimilation starts from previous global analysis, validity time 6 hours earlier.
Initialisation	None.

7.2.2 Forecast model

Basic equations	Hydrostatic primitive equations with approximations accurate on planetary scales. (White & Bromley, 1995)
Independent variables	Latitude, longitude, eta , time
Dependent variables	Horizontal wind components, potential temperature, specific humidity, specific cloud water (liquid and frozen), surface pressure, soil temperature, soil moisture content, canopy water content, snow depth, sea-ice temperature, boundary-layer depth, sea-surface roughness.
Diagnostic variables	Geopotential, vertical velocity, convective-cloud base, top, amount, and layer-cloud amounts.
Integration domain	Global.
Horizontal grid	Spherical latitude-longitude with poles at 90°N and 90°S. Resolution: 0.83° latitude, and 1.25° longitude. Variables staggered on Arakawa B-grid.
Vertical grid	19 levels, hybrid co-ordinates (eta = A/p_0 +B);
	layer boundaries at 1.0, 0.994, 0.956, 0.905, 0.835, 0.75, 0.65, 0.55, 0.46, 0.385, 0.325, 0.275, 0.225, 0.175, 0.125, 0.075, 0.04, 0.02, 0.01, 0.0005;

	levels are (assuming surface pressure of 1000 hPa): 997, 975, 930, 870, 792, 700, 600, 505, 422, 355, 300, 250, 200, 150, 99, 57, 30, 15, 4.6 hPa.
Integration scheme	Split-explicit finite difference. Adjustment uses forward-backward scheme, second-order accurate in space and time. Advection uses a two-step Heun scheme with fourth-order accuracy. Adjustment timestep =200s; advection timestep =600s; physics timestep =1200s.
Filtering	Fourier damping of mass-weighted winds and mass-weighted increments to potential temperature and humidity. Adapts to strength of wind at each latitude.
Horizontal diffusion	Linear fourth order with coefficient $K = 4.0 \times 10^7$ (but linear, second order on top level with $K = 1.0 \times 10^6$) for winds, liquid potential temperature and total water content. No diffusion where co-ordinate surfaces are too steep (near orography).
Vertical diffusion	Second-order diffusion of winds only between 500 & 150 hPa in Tropics (equatorwards of 30°).
Divergence damping	Nil.
Orography	Grid-box mean, standard deviation and sub-grid-scale gradients (for gravity wave surface stress) derived from US Navy 10' dataset. Orographic roughness parameters linearly derived from standard deviation, and from 1 km data (N.America) and 100m data (Europe).
Surface classification	Sea: global SST analysis performed daily.
	Sea ice: Analysis using ice edge data from Washington Joint Ice Center. No partial cover, thickness = 2m.
	Land: geographical specification of vegetation and soil types that determine surface roughness, albedo, heat capacity, and surface hydrology; snow amount from modified monthly climatology of Willmott et al. (1985).

Physics parametrisations:

a) Surface and soil	Multi-layer soil-temperature model. Soil-moisture and surface-moisture flux prediction scheme with surface canopy store (Warrilow and Buckley, 1989). Sea-surface roughness dependent on wind speed (Charnock constant = 0.12). Surface fluxes of heat, moisture and momentum dependent on surface roughness and local stability.
b) Boundary layer	Turbulent fluxes in lowest 5 layers depend on moist local stability and low-cloud cover (Smith, 1990). Implicit integration scheme. Non-local mixing of heat and moisture in unstable conditions. Form drag effects modelled via an effective roughness length calculated from the silhouette area of unresolved orography and standard deviation of orography height within the grid box.
c) Cloud/precipitation	Liquid and ice content included. Large-scale precipitation takes into account accretion and coalescence for rain. Frozen cloud starts precipitating as soon as it forms (Smith, 1990). Evaporation of precipitation depends on phase, temperature and rate.
d) Radiation	Fully interactive using 6 bands in the long-wave and 4 in solar calculations. Long-wave gaseous transmission adapted from Morcrette *et al.* (1986). Fractional cloud in all moist layers and convective tower. Cloud emissivity and optical properties depend on phase and water content (Slingo, 1989).
e) Convection	Penetrative mass-flux scheme based on a simple cloud model (Gregory and Rowntree, 1990). Initial mass flux depends on buoyancy. Downdraught representation included. Convective momentum transports included.
f) Gravity-wave drag	Surface stress estimated from sub-grid variance of orography. and the orography gradient vector; high drag states, flow blocking, and drag due to trapped lee waves are represented. Vertical stress profile for hydrostatic waves determined by critical saturation stress law similar to Palmer et al., (1986).

7.2.3 Numerical weather prediction products

RSMC Bracknell issues products on the GTS from the global numerical forecast models using several code forms. The character based format code is FM47 GRID and the binary format code is FM92 GRIB Ext. X. However, there remain some products that will be issued in the obsolete code FM92 Ext. VIII format until July 1997 when they will be withdrawn. NWP model fields are interpolated onto regular latitude-longitude grids arranged in adjacent areas to give global coverage in GTS bulletins that do not exceed the GTS size limit. The regular products from the global atmospheric and wave models are on a 2.5 x 2.5 degree resolution. WAFS bulletins from the atmospheric model in the Thinned GRIB format of 140km (1.25 x 1.25 degrees at the equator) are available over SADIS, but these bulletins, and the rest of the bulletins making up a full forecast product, are also available over high capacity links on the GTS. Fields from the atmospheric model include geopotential height, temperature, horizontal wind on all standard levels, vertical velocity and relative humidity on some standard levels, mean sea level pressure and precipitation. From the wave model, height, direction and period of total significant wave, swell and wind-sea are available. Forecast times include the analysed data (T+0) and at 6 or 12 hour steps out to

T+120. More detailed information is available in the "List of Numerical Weather Prediction Products Available from Bracknell", published by the Meteorological Office.

In the event of a system failure at Bracknell, backup procedures are started when it becomes apparent that delays to the current run will lead to failure to meet the output schedules. At present this occurs if there is a delay of 20 minutes to the global model output. If the delay is less than 12 hours, all the normal output is generated from the previous run. The previous T+36 becomes the new T+24, for example, and the previous T+12 becomes the new T+0. If the delay is greater than 12 hours, and the previous run was not completed, then a limited number of products from Washington WMC are issued in place of the normal Bracknell output.

7.2.4 Operational techniques for application of NWP products

MOS (Model Output Statistics) applications to estimate maximum and minimum temperature and probability of precipitation (PoP) are used internally at Bracknell. Forecasts of maximum and minimum temperature are available out to 6 days for European stations and for a selection of stations world-wide. PoP forecasts are created for all UK and many European stations in 12 hour periods out to 6 days.

7.3 Regional forecasting system

7.3.1 Data assimilation

The data assimilation scheme for the regional model is identical to that for the global model in all respects except the following:

Analysis domain	Eastern USA, Canada, all of Atlantic north of 30°N, Europe and the Mediterranean.
Horizontal grid	Spherical rotated latitude-longitude with pole at 30°N, 160°E. Resolution: 0.44°.
Assimilation method	Data grouped into 3-hour time windows centred on analysis hour for quality control.
Assimilation model	As regional forecast model (see 7.3.2) but with divergence damping of 0.5 x 10^6 m^2s^{-1} included.
Assimilation cycle	Data assimilation starts from a previous regional model analysis, validity time 3 hours earlier.
Data	A Moisture Observation Pre-processing System is used to blend model first-guess information, satellite and radar imagery along with surface cloud reports to produce a 3-dimensional cloud analysis. This is converted to give vertical profiles of relative humidity at each model grid point for assimilation by the regional model. The area of coverage is roughly 63.5N, 21.0W - 62.5N, 22.5E - 41.0N, 13.0W - 40.5N, 12.5E.

7.3.2 Forecast model

The regional forecast model is identical to the global model in all respects except the following:

Integration domain	Eastern USA, Canada, all of Atlantic north of 30°N, Europe and the Mediterranean.
Horizontal grid	Spherical rotated latitude-longitude with pole at 30°N, 160°E. Resolution: 0.44°.
Timestep	Adjustment timestep =100s; advection timestep =300s; physics timestep =900s.
Integration Scheme	Advection scheme is second-order accurate.
Filtering	None required.
Horizontal diffusion	Linear fourth-order with coefficient $K = 1.7 \times 10^7$ for winds, liquid water, potential temperature, and total water content. Linear second-order with coefficient $K = 4.25 \times 10^6$. No diffusion where co-ordinate surfaces are too steep (near orography).
Vertical diffusion	None.
Boundary values	Specified from global forecast model with data time HH-12 or HH-6 (HH = analysis time of regional model). Linear time interpolation from hourly values and spatial interpolation to rotated co-ordinates. Values applied over rim of 4 points with weights of 1.0, 0.75, 0.5, and 0.25.

Physics parametrisations:

d) Radiation	Long-wave gaseous transmission treated as in Slingo & Wilderspin (1986).
e) Convection	No convective momentum transports.

7.3.3 Numerical weather prediction products

RSMC Bracknell issues products on the GTS from its regional numerical forecast models using several code forms. The character based format code is FM47 GRID and the binary format code is FM92 GRIB Ext. VIII. NWP model fields are interpolated onto regular latitude-longitude grids arranged in adjacent areas covering Europe and the North Atlantic. The products from the regional atmospheric model are currently on either a 1.25 x 1.25 or a 2.5 x 2.5 degree resolution. The regional wave model products are on a 1.25 x 1.25 degree resolution. Fields from the regional atmospheric model include geopotential height, temperature, horizontal wind on all standard levels, vertical velocity and relative humidity on some standard levels, mean sea level pressure and precipitation. From the wave model, height, direction and period of total significant wave, swell and wind-sea are available. Forecast times include the analysed data (T+0) and at 3 or 6 hour steps out to T+36. More detailed information is available in the "List of Numerical Weather Prediction Products Available from Bracknell", published by the Meteorological Office.

In the event of a system failure at Bracknell, backup procedures are started when it becomes apparent that delays to the current run will lead to failure to meet the output schedules. At present this occurs if there is a delay of 10 minutes to the regional model output. If the delay is less than 6 hours, all the normal output is generated from the previous run. The previous T+36 becomes the new T+30, for example, and the previous T+12 becomes the new T+6. If the delay is greater than 12 hours, and the previous run was not completed, then products from the run 12 hours before are used.

7.3.4 Operational techniques for application of NWP products

MOS (Model Output Statistics) applications to estimate maximum and minimum temperature and probability of precipitation (PoP) in 6 hour periods to T+36, for UK stations, are used internally at Bracknell. Trajectory forecasts are created for application in 1-dimensional vertical profile models. Wind fields are used for forcing surge models.

7.4 Mesoscale forecasting system

7.4.1 Data assimilation

The data assimilation scheme for the mesoscale model is identical to that for the regional model in all respects except the following:

Analysis domain	British Isles and surrounding sea areas, near continental Europe and southern Norway (approximately 60°N-47°N, 12°W-7°E).
Horizontal grid	Spherical rotated latitude-longitude with pole at 37.5°N, 177.5°E. Resolution: 0.15°.
Assimilation model	As mesoscale forecast model (see 7.4.2) but with divergence damping of 1.0×10^5 m^2s^{-1} included.
Assimilation cycle	Continuous sequence of 3-hourly mesoscale assimilation cycles.
Data	Hourly screen temperature, humidity and surface wind data are assimilated by the mesoscale model along with hourly rather than 3-hourly surface pressure data. A precipitation rate analysis derived from radar and surface reports is used to calculate assimilation increments to the canopy water, soil moisture and snow depth fields.

7.4.2 Forecast model

The mesoscale forecast model is identical to the regional model in all respects except the following:

Integration domain	British Isles and surrounding sea areas, near continental Europe and southern Norway (approximately 60°N-47°N, 12°W-7°E).
Horizontal grid	Spherical rotated latitude-longitude with pole at 37.5°N, 177.5°E. Resolution: 0.15°.
Vertical grid	31 levels, hybrid co-ordinates (eta = A/p_0 +B);
	layer boundaries at 1.000, 0.9976, 0.9929, 0.9835, 0.9719, 0.958, 0.940, 0.921, 0.901, 0.880, 0.858, 0.835, 0.810, 0.780, 0.745, 0.705, 0.660, 0.610, 0.555, 0.500, 0.445, 0.385, 0.325, 0.275, 0.225, 0.175, 0.125, 0.075, 0.040, 0.020, 0.010, 0.0005;
	levels are (assuming surface pressure of 1000 hPa): 999, 995, 988, 978, 965, 949, 930, 911, 890, 869, 846, 822, 795, 762, 725, 682, 635, 582, 527, 472, 415, 355, 300, 250, 200, 150, 99, 57, 30, 15, 4.6 hPa.
Timestep	Adjustment timestep = 33.3s; advection timestep = 100s; physics timestep = 300s.
Horizontal diffusion	Linear fourth-order with coefficient K = 3 x 10^6 for winds, liquid water, potential temperature, and total water content. No diffusion where co-ordinate surfaces are too steep (near orography).
Vertical diffusion	None.
Orography	Grid-box mean and variance derived from 5' NCAR dataset. Orographic roughness parameters derived from 100m data.
Boundary values	Specified from regional forecast model with same data time HH (forecasts from 00, 06, 12 and 18 UTC) including 6 hours of data assimilation starting HH-6.

Physics parametrisations:

a) Surface	Land use characteristics are based on 10 minute data, rather than 1 degree.
b) Boundary layer	Turbulent fluxes in lowest 14 layers depend on moist local stability and low-cloud cover (Smith, 1990) and with non-local mixing in unstable conditions. Implicit integration scheme.
d) Radiation	As coarser models but updated hourly rather than 3-hourly. All have solar angle updated each timestep. A random/maximum overlap assumption is used for long-wave calculations.
e) Convection	Updated version of Gregory and Rowntree scheme (1990) to include downdraught parametrisation and revised evaporation formulae dependent on the precipitation rate.
f) Gravity-wave drag	None.

7.5 Transport and dispersion model

A model for medium and long-range transport and dispersion (NAME, version 2.1) is available to be run in the event of a nuclear emergency or other large-scale release of hazardous materials into the atmosphere. It can also be used for routine pollution problems, such as acid rain episodes. It provides forecasts of concentrations in the boundary layer and at upper levels, as well as wet and dry deposition

to the surface. It uses analysis and forecast fields from the global and regional atmospheric models maintained in on-line archives. The NAME model may be run at any time in hindcast or forecast mode.

Model type	Three-dimensional Lagrangian multiple-particle Monte Carlo model simulating the medium or long-range transport, dispersion and deposition of airborne pollutants, including accidentally released radionuclides.
Integration domain	Global, Europe/North Atlantic Regional or UK Mesoscale, nested as required.
Model grid	Identical to the Global, Limited-Area or UK Mesoscale models, but with some vertical levels omitted. The transport model can access fields from all three input models simultaneously, with an option to use the best resolution available at every particle position. The output grid can be customer-defined, and of any resolution.
Dynamical input	Meteorological fields from the Global, Limited-Area or UK Mesoscale models.
Integration scheme	Forward timestep, determined by the diffusion scheme near to the source, but with an option for definition by the user in the longer ranges.
Parametrisation	Comprehensive near-source random walk diffusion scheme with option of uniform or non-homogeneous vertical profiles of the turbulent velocity variances and, for the convective boundary layer, an option for non-Gaussian statistics. Simpler, homogeneous scheme at longer ranges, or an option for basic K-diffusion. There are also schemes for low-frequency wind meandering, plume rise, the venting of pollutants from the boundary layer by strong convection, and a novel technique allowing for small-scale entrainments at the boundary layer top. Radioactive decay; wet and dry deposition, with provision for conversions from gas to particulate; turbulent (occult) deposition over hills.
Special features	10-day high-resolution (6 km) archive of rainfall rate, derived from radar and satellite imagery or mesoscale NWP products, used for wet deposition over NW Europe; effects of orographic enhancement and scavenging by snow included. Automated adjustments to plume spread and source emission profile from observed radiology using least-squares techniques.

7.6 Nowcasting system

Nimrod produces analyses and forecasts of precipitation and supplementary weather parameters (including precipitation type, snow probability and lightning rate), at 5km resolution, for the period T+0 to T+6 hours. Forecasts are produced using a combination of linear extrapolation and model wind advection, with precipitation forecasts from the Mesoscale Model used to introduce an element of growth/decay. In addition, analyses and forecasts of cloud amount (3-D), cloud base and cloud top height are generated. These products are generated hourly at a resolution of 15km. The Nimrod cloud and precipitation analyses are used as inputs to the Mesoscale model assimilation scheme. A cloud analysis is also generated on an extended domain, at 45km resolution, for input to the Regional Model data assimilation scheme.

Grid	UK national grid: 5km resolution for precipitation products; 15km resolution for cloud products. The domain is a close approximation to the Mesoscale model grid (47°N-60°N, 12°W-7°E).
Data inputs	Radar imagery (from the network of 15 sites within the UK and Ireland), Meteosat visible and infrared imagery, Mesoscale and Limited-Area model forecast fields and surface weather reports.
Forecast timestep	15 minutes for precipitation forecasts; 60 minutes for cloud forecasts.
Special features	Radar rain rates automatically corrected for the effects of bright-band, range and orographic growth using a physically based method (Kitchen et al., 1994)

7.7 Wave hindcast and forecasting system

7.7.1 Global wave model

Model type	Coupled discrete (SWAMP,1985); deep water solution only.
Integration domain	Global.
Grid	Spherical latitude-longitude from 80.4°N to 77.0°S. Resolution: 0.83° latitude, 1.25° longitude.
Frequency resolution	13 frequency components spaced logarithmically between 0.04Hz and 0.324Hz.
Direction resolution	16 equally spaced direction components.
Data assimilation	ERS-2 altimeter wave height observations are assimilated into the global wave model, using the altimeter wind-speed to separate wind-sea and swell. The assimilation scheme (Thomas, 1988, and Stratton *et al.*, 1990) is a variant of the analysis-correction scheme of Lorenc *et al.* (1991). After assimilation the model wave height matches the analysed wave height, the model wind-sea matches the analysed wind-speed, and the pattern of the spectrum remains similar to that before assimilation.
Integration scheme	Modified Lax-Wendroff. Source terms timestep = 3600s; advection timestep frequency dependent.
Boundary forcing	Winds at lowest level of global atmospheric model (23m). Updated hourly.
Surface classification	Sea ice analyses the same as global atmospheric model.
Physics parametrisations:	Linear growth (Phillips, 1958); exponential growth (Snyder, 1981); white-capping dissipation (Komen et al., 1984). Non-linear transfer of wave energy is parameterised by enforcing a JONSWAP spectral shape on the wind-sea. A parametrisation of directional relaxation in turning winds is included, and a term accounting for the great-circle turning of swell energy is applied. For wind speeds lower than 7.3 ms^{-1} a parametric growth term is used to calculate windsea growth. For all but actively growing windsea, the dissipation coefficient is reduced by one half of the specified value.

7.7.2 Regional wave model

Apart from having no data assimilation, the formulation of the regional wave model is identical to the global wave model in all respects except the following:

Model type	Coupled discrete; depth dependency specified to 200m with 2m resolution.
Integration domain	European continental shelf and Mediterranean, Baltic and Black Seas.
Grid	Spherical latitude-longitude from 67.7°N to 30.5°N, and from 14.1°W to 41.9°E. Resolution: 0.25° latitude, 0.4° longitude.
Source terms timestep	1800s.
Boundary forcing	1. Winds at lowest level of regional atmospheric model (23m). Updated hourly. 2. Spectral values at lateral boundaries from global wave model. Updated hourly.
Surface classification	No sea ice.
Physics parametrisations:	Identical to global model, without great-circle turning of swell, but with refraction and bottom friction (Collins, 1972).

---

8. VERIFICATION OF FORECAST PRODUCTS (1996)

Statistic	Parameter	Area	Verified against	T+24	T+72	T+120
RMS error (m)	Z 500	N.Hem	Analyses	13.3	36.7	63.1
RMS error (m)	Z 500	S.Hem	Analyses	21.6	57.9	89.5
RMS error (m)	Z 500	N.America	Observations	18.5	41.0	66.5
RMS error (m)	Z 500	Europe	Observations	16.0	36.8	64.3
RMS error (m)	Z 500	Asia	Observations	20.4	32.1	47.5
RMS error (m)	Z 500	Aus/NZ	Observations	16.6	34.3	52.9
RMSVW error (m/s)	W 250	N.Hem	Analyses	5.3	11.1	16.3
RMSVW error (m/s)	W 250	S.Hem	Analyses	5.7	13.9	19.7
RMSVW error (m/s)	W 250	N.America	Observations	7.8	13.7	19.1
RMSVW error (m/s)	W 250	Europe	Observations	7.1	12.1	18.0
RMSVW error (m/s)	W 250	Asia	Observations	7.9	11.7	15.0
RMSVW error (m/s)	W 250	Aus/NZ	Observations	8.0	12.8	17.3
RMSVW error (m/s)	W 850	Tropics	Analyses	2.4	3.8	4.5
RMSVW error (m/s)	W 250	Tropics	Analyses	4.3	7.4	9.2
RMSVW error (m/s)	W 850	Tropics	Observations	4.4	5.3	5.7
RMSVW error (m/s)	W 250	Tropics	Observations	7.1	8.6	9.8

1. The annual figures above are averages of the 12-monthly figures derived according to the standard verification methods specified by the CBS.
2. Results for verification against analyses show the average of the 00 UTC and 12 UTC values at all three forecast times.
3. Results for verification against observations show the average of the 00 UTC and 12 UTC values at T+24, T+72 and T+120. Results for Aus/NZ are for 00 UTC only.

---

9. PLANS FOR THE FUTURE

9.1 Computer systems

The first phase of the installation of a Cray T3E MPP (Massively Parallel Processor) was completed during October '96. This initial system is currently being used for user testing and the migration of application software to the new architecture. After a series of planned upgrades and testing, the system will become operational in late spring/early summer, at which time the C90 will be taken out of service. The system in its final configuration is expected to have at least five times the capacity of the C90.

9.2 Data assimilation

The data assimilation code has been changed for efficient implementation on the Cray T3E in May 1997.

A minor retuning will be undertaken to reflect the model resolution and domain changes planned for the summer of 1997 (see 9.3).

The major development activity continues to be the development of a variational assimilation system, which is expected to replace the current analysis correction scheme around the end of 1997.

A number of changes are planned in the area of satellite data assimilation:

- improve systems for assimilation of TOVS radiances;
- implement assimilation of ATOVS radiances;
- improve use of satellite winds, and implement use of new types of satellite wind;
- implement assimilation of information on humidity and surface wind from SSM/I brightness temperatures;
- improve use of ERS/2 scatterometer data; investigate use of ADEOS NSCAT data;
- improve the assimilation of cloud information in geostationary imagery;

9.3 Atmospheric forecast models

The horizontal and vertical resolution of the global model will be improved to ~60km and 30 levels. At the same time, the regional model will be discontinued. The mesoscale model is likely to cover a slightly enlarged domain and receive boundary values from the global model.

With the implementation of the new global and mesoscale models, the system run schedule will change substantially. The two main global medium range forecasts (to T+144) will run from 06 UTC and 18 UTC with a 2 hour data cut-off. Shorter range forecasts (to T+48) will be made at 00 UTC and 12 UTC, also with a 2 hour data cut-off. There will also be T+48 runs at these times with a 3 hour data cut-off, primarily for aviation purposes and to confirm the synoptic development.

The surface hydrology scheme for the mesoscale and regional models will be revised.

A more accurate radiation scheme will be introduced.

9.4 Wave forecast models

The WAM model (cycle 4) is now included within the Unified Model system. Future work will allow nested wave models to be run through this system.

The spatial resolution for the global wave model is expected to increase during 1997, in line with changes to the operational global NWP model (see 9.3 above). Shallow water physics will be included in the high resolution global wave model.

The spatial resolution and coverage of the regional wave model are also expected to change during 1997.

9.5 Ocean forecast models

It is planned to introduce a global ocean forecast model into operational use during 1997. At 1° by 1°

resolution, with 20 levels in depth, the ocean model will assimilate available oceanographic observations, and be forced by surface fluxes from the operational global NWP model, providing forecasts out to 5 days ahead.

9.6 Nowcasting System

The range of products generated by the Nimrod system will be extended to include analysis and forecasts of visibility.

The Nimrod system domain will be extended in line with changes to the Mesoscale model domain.

---

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Unified Model User Guide

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Part V

THE UNIFIED MODEL USER GUIDE

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Preface

This document is the User Guide for the Unified Model (UM). It gives basic information on how to use the model and includes references to relevant UM Documentation Papers (UMDPs) where more detailed information is required.

Chapter 1 provides the introduction. It gives an overview description of the UM and its development history. Chapter 2 contains information describing various aspects of Numerical Weather Prediction and the Unified Model. It is intended to help explain how the UM works but does not explain how to use it. That is covered in chapter 3 which is the main part of the User Guide. It contains instructions on how to use various parts of the UM and how to perform particular tasks.

The User Guide is intended for use both by users at the Met. Office and external users of the UM. It also contains additional information relating to the particular set up at the Met. Office. Where information is specific to one set of users it has been put into the appropriate appendix (appendix A for the Portable UM and appendix B for Met. Office specific information).

This document was written in LaTeX and is available in both HTML and PostScript forms. The HTML form contains links to allow easy navigation around the document and also out to external documents (such as UMDPs, source code listings, etc). External users will find that some of these links will not work since they are specific to the Met. Office or have not been configured.

If you have any contributions, corrections, or any other feedback concerning this document please contact the editor at the following email address:

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- `dmatthews@meto.govt.uk` (external)

Chapter 1

Introduction

1.1 The Unified Model

Author: Alan Dickinson, Last Updated: 12 Apr 96

1.1.1 Overview

The Unified Model is the name given to the suite of atmospheric and oceanic numerical modelling software developed and used at the Met Office. The formulation of the model supports global and regional domains and is applicable to a wide range of temporal and spatial scales that allow it to be used for both numerical weather prediction and climate modelling as well as a variety of related research activities. The Unified Model was introduced into operational service in 1991. Since then, both its formulation and capabilities have been substantially enhanced.

The modelling system is designed so that it can be run in atmosphere-only, ocean-only or in coupled mode. A number of sub-models are also available which may be used in place of or in addition to the main models. These include a simplified model of the ocean, known as the slab model, and models to simulate the motion of sea ice. A typical run of the system consists of an optional period of data assimilation followed by a prediction phase. Forecasts from a few hours to a few days ahead are required for numerical weather prediction while for climate modelling the prediction phase may be for tens, hundreds or even thousands of years. The choice of horizontal and vertical resolution is arbitrary and may be varied by the user. In practice, the resolution is constrained by the available computing power and a number of standard resolutions tend to be used (see table 1.1). A separate reconfiguration module allows model data to be optionally interpolated to a new grid or area prior to the start of a run.

Application	Status	Resolution (degrees)	Grid (E-W x N-S)	Levels
Climate Modelling	Research	5.00 x 7.50	48 x 37	19
Climate Modelling	Production	2.50 x 3.75	96 x 73	19
Middle Atmosphere	Research	2.50 x 3.75	96 x 73	42
Weather Forecasting	Production	1.25 x 0.83	288 x 217	19
Weather Forecasting	Research	0.83 x 0.56	432 x 325	30

Table 1.1: Global atmospheric configurations of the Unified Model used for production and research at the Met Office

A range of ancillary data may be incorporated into the model as a run progresses. The options range from

lateral boundary forcing information for regional configurations to the periodic updating of fields such as ozone concentration to allow for the effects of seasonal variations.

Prognostic, diagnostic and derived fields of data may be output on a time-step by time-step basis for inspection and further analysis, or as forcing information for sub-models such as a sea-state prediction model.

The wide range of options available within the Unified Model system means that a large number of parameters need to be defined in order to specify and control a particular model configuration. A user-friendly X-Windows based user interface has been developed to make this task much easier. By use of interactive windows, a user may control parameters such as model resolution, the date and time of the initial data, the length of forecast, the choice of output diagnostics and so on. The user may also control the scientific content of the model by selecting from a library of alternative representations of the physical processes.

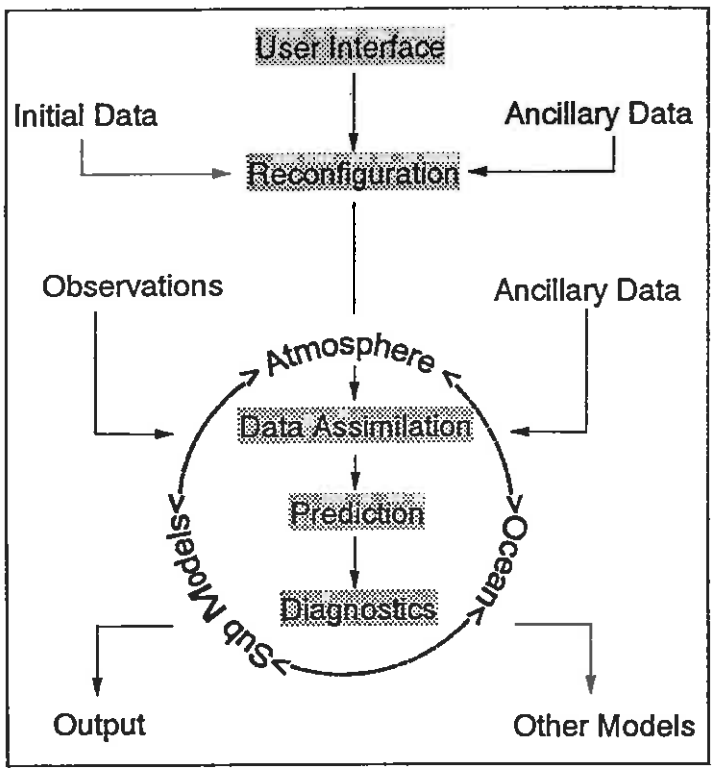

Figure 1.1: The main components of the Unified Model system

1.1.2 Formulation

The main atmospheric and oceanic components of the model are described below. In addition to these, a number of internal sub-models may be linked into the system. These include models of sea-ice and an ocean "slab" model. Development of further sub-model options is in progress and will include atmospheric chemistry and a model of the sea-state.

Atmospheric Prediction

The atmospheric prediction component uses a set of equations that describe the time-evolution of the atmosphere. The equations are solved for the motion of a fluid on a rotating, almost-spherical planet. The main variables are the zonal and meridional components of the horizontal wind, potential temperature and specific humidity. To solve the system of equations, a number of approximations or assumptions have to be made. In common with most other atmospheric models the Unified Model's atmospheric prediction scheme is based on

the so-called hydrostatic primitive equations. This means that the model atmosphere is always in hydrostatic balance which means that there are no vertical accelerations. Most other atmospheric models also make the shallow-atmosphere approximation which derives its name from the fact that the depth of the atmosphere is much smaller than the radius of the Earth. The Unified Model does not make this assumption. This makes the equations a little more complicated to solve by adding in extra terms which can be important when planetary-scale motions are considered.

The equations can be solved in a variety of different ways. The Unified Model uses a grid-point scheme on a regular latitude-longitude grid in the horizontal and a hybrid vertical grid, which is terrain-following near the surface but evolving to constant pressure surfaces higher up. An efficient split-explicit scheme is used to solve the equations which is designed to conserve mass, mass-weighted potential temperature and moisture and angular momentum. These are important to ensure the integrity of the solutions for long integrations required for climate-change experiments.

The physical processes represented include:

- Atmospheric radiation allowing for the effects of clouds, water vapour, ozone, carbon dioxide and a number of trace gases.
- Land surface processes including a multi-layer soil temperature and moisture prediction scheme.
- A treatment of the form drag due to the sub-grid scale variations in orography.
- Vertical turbulent transport within the boundary layer.
- Large-scale precipitation determined from the water or ice content of a cloud.
- The effects of convection through a scheme based on the initial buoyancy flux of a parcel of air. It includes entrainment, detrainment and the evaporation of falling precipitation. An explicit treatment of downdraughts is included.
- The effects of the drag caused by vertically propagating gravity waves is modelled using sub-grid scale orographic variance and known absorption properties of gravity waves.

Lateral boundary values may be output from larger scale integrations to support the running of regional configurations of the model. Regional configurations of the model are typically used to produce forecasts at much higher spatial resolutions than could be obtained within the available computing resources using global configurations of the model. A number of regional domains may be nested within each other. Regional configurations of the model use a rotated latitude-longitude grid which ensures a quasi-uniform grid length over the whole integration domain.

Oceanic Prediction

Ocean processes are represented by an ocean model that has been derived from that originally developed at the Geophysical Fluid Dynamics Laboratory, Princeton, USA. This is based on a finite difference representation that uses a spherical coordinate system in the horizontal and geometric depth as the vertical coordinate. It solves equations for the motion of the ocean that are similar to those used in the atmospheric component. The main variables used by the ocean model are: currents, potential temperature and salinity. In addition to the dynamical processes, the model includes representations of the following physical processes:

- Mixing in the upper ocean.
- Heating and cooling by surface fluxes, some of which can penetrate below the surface.

- Diffusion along isopycnal surfaces.

Ocean properties evolve over many centuries, so the model includes modifications to the equations of motion that allow it to run for long periods to attain equilibrium solutions.

Biological and chemical processes are important on the longer timescales used in climate modelling. The ocean model contains representations of biological life cycles and their effects on the carbon budget of the ocean.

Sea ice has a major impact on the climate of both the atmosphere and ocean. Within the ocean model there are several options for simulating sea ice, ranging from a scheme that assumes the ice to be stationary through to one in which the ice moves in response to winds, currents and the internal stresses of the ice.

Data Assimilation

Atmospheric and oceanic data assimilation is performed using an analysis correction scheme. This is an iterative analysis, with each variable being analyzed in turn. Appropriate constraints are included so as to improve balance and speed of convergence. In the atmosphere these include hydrostatic temperature increments derived from the analyzed surface pressure increments; geostrophic wind increments derived from the analyzed mass increments; and surface pressure and temperature increments derived from the analyzed wind increments using a linear balance relationship. Each iteration is interleaved with a timestep of the full forecast model to nudge the forecast model solution towards the observations. Observations are introduced into this continuous assimilation over a period around their validity time, with a peak weighting at their validity time. The extent of horizontal data spreading is determined by a continuous background error correlation function which has a time dependence such that progressively smaller scales are fitted.

1.1.3 Applications

The model is used by the Met Office for operational numerical weather prediction and by the Hadley Centre for Climate Prediction and Research to simulate and predict the Earth's climate. The model is also used by a number of meteorological centres and research organisations worldwide.

Numerical Weather Prediction

The Unified Model is used operationally at the Met Office to provide numerical forecasts of the atmospheric state for periods of a few hours to several days ahead. Both global and regional configurations are used, with the larger scale model providing lateral boundary values for higher resolution regional models. Several runs are made throughout each day against a fixed schedule and tight deadlines.

A number of major improvements to the scientific formulation of the Unified Model have been made during its lifetime. These have led to significant gains in the quality of operational forecasts (see figure 1.2).

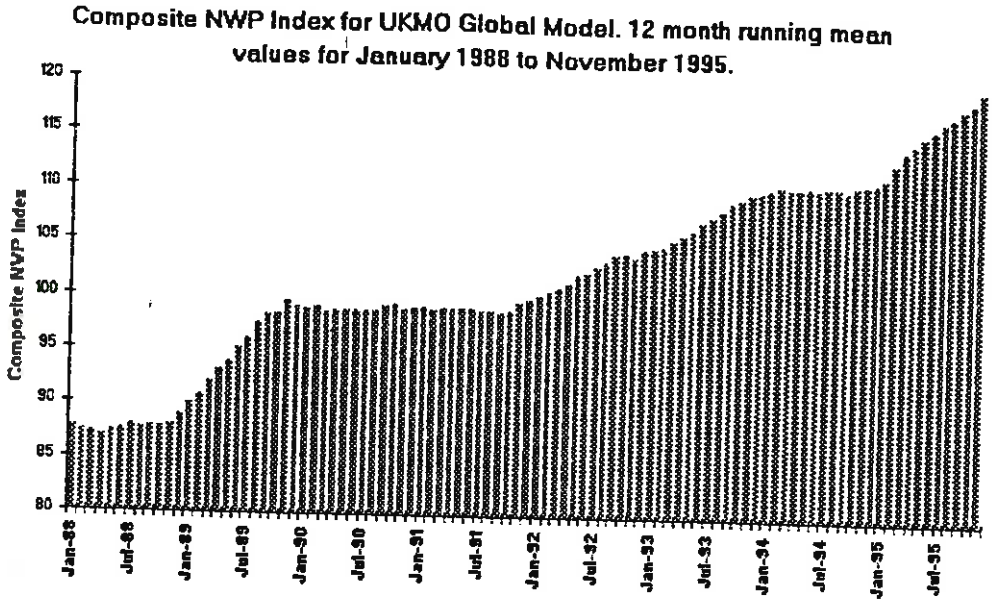

Figure 1.2: The skill of Met Office operational global forecasts as measured by the NAO index. The index increases as the skill of the forecasts improves. It is based on a scaled, weighted average of the root mean square errors of a range of key forecast fields. The Unified Model was introduced into operational service in June 1991.

Limited-area, regional configurations of the Unified Model are used to provide detailed guidance of the weather in the region of the United Kingdom (see figure 1.3).

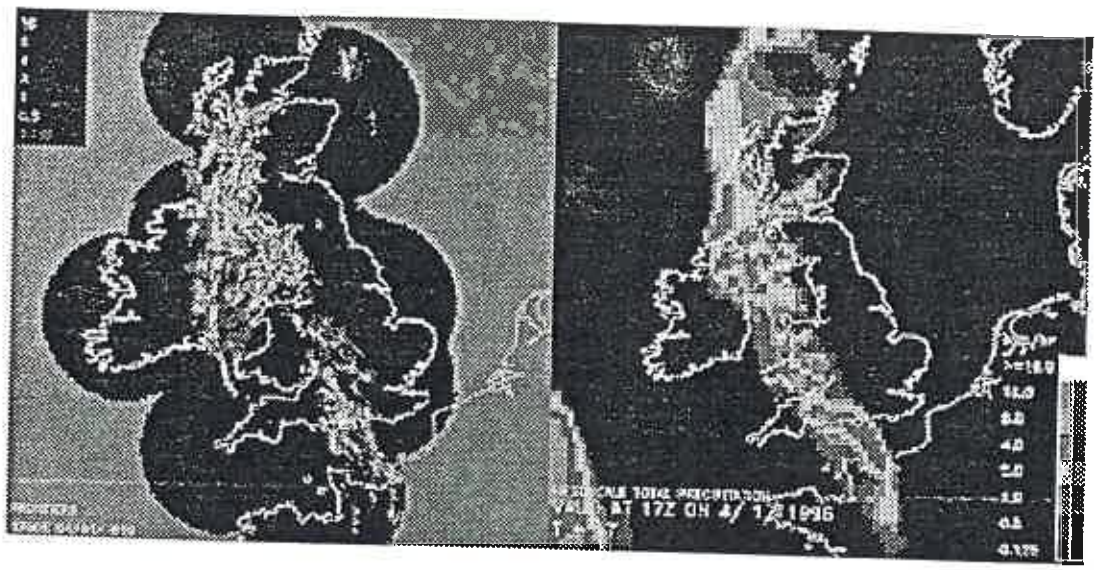

Figure 1.3: A 12 hour forecast of precipitation intensity obtained using a high resolution (17Km) regional configuration of the Unified Model (right). The observed precipitation as measured by the UK radar network is also shown (left).

Oceanographic Forecasting

FOAM, the Forecasting Ocean Atmosphere Model, is being developed to produce analyses and short-range forecasts of the ocean's temperature and salinity structure. It is based on the oceanic component of the Unified Model and is driven by surface fluxes of heat, fresh water, and momentum that are calculated from operational runs of the atmospheric component of the Unified Model.

Because FOAM is intended for short-range integrations, the oceanic initial state is very important. The success of FOAM is therefore very dependent on the quality of the Unified Model's data assimilation scheme.

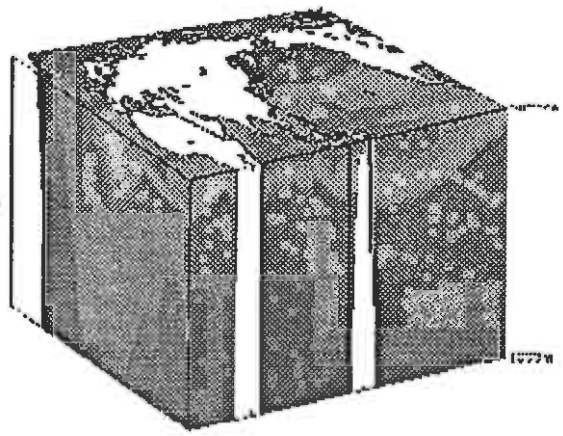

Figure 1.4: The ocean temperature structure as analysed by FOAM

1.1.4 Climate Prediction

The prospect of climate change due to man's activities is a high profile scientific and political issue. The threat of global warming due to the steady increase in atmospheric concentrations of greenhouse gases has led to renewed efforts to understand the factors influencing the Earth's climate and to predict the extent and impact of climate change over the next century.

The Hadley Centre uses the Unified Model both to simulate the present climate in order to understand its natural variability and to predict global and regional climate change up to the end of the 21st century. Climate prediction requires models of the atmosphere, ocean, land surface and sea ice to be run in coupled mode so that the interactions between them are represented.

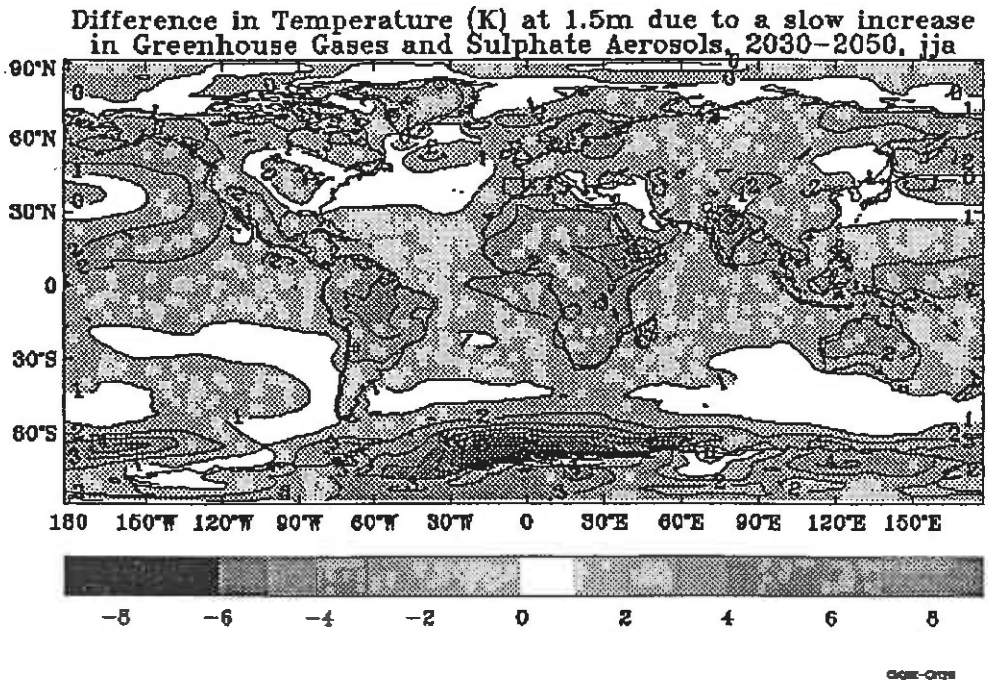

Figure 1.5: A prediction of global temperature change

Middle Atmosphere Research

Daily analyses of the stratosphere are carried out at the Met Office using a version of the Unified Model's data assimilation scheme. The analyses are used in a variety of applications which are aimed at a better understanding of the dynamics and chemistry of the stratosphere. In particular, the analyses have proved invaluable in the interpretation of measurements from the Upper Atmosphere Research Satellite.

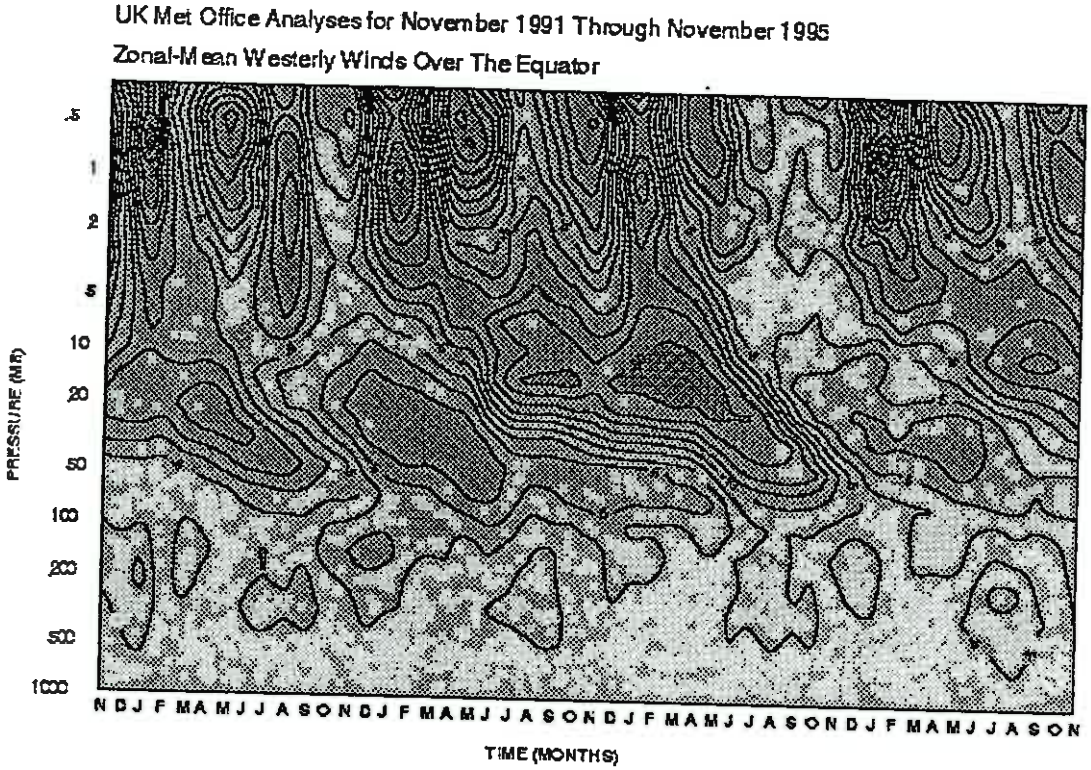

Figure 1.6: Time series of winds over the equator, analysed using the stratospheric configuration of the Unified Model. The winds show a clear Quasi-Biennial Oscillation in the stratosphere and a Semi-Annual Oscillation near the stratopause.

1.1.5 Features and Capabilities

User Interface

The Unified Model is a very flexible system allowing a vast number of choices. To help the user make the most of this flexibility, a graphical user interface, known as the UMUI (Unified Model User Interface), has been developed. The UMUI is X-Windows based and runs in the familiar environment of the user's own local workstation (see figure 1.7). It is designed to give access to the full functionality of the Unified Model whilst speeding up the learning process.

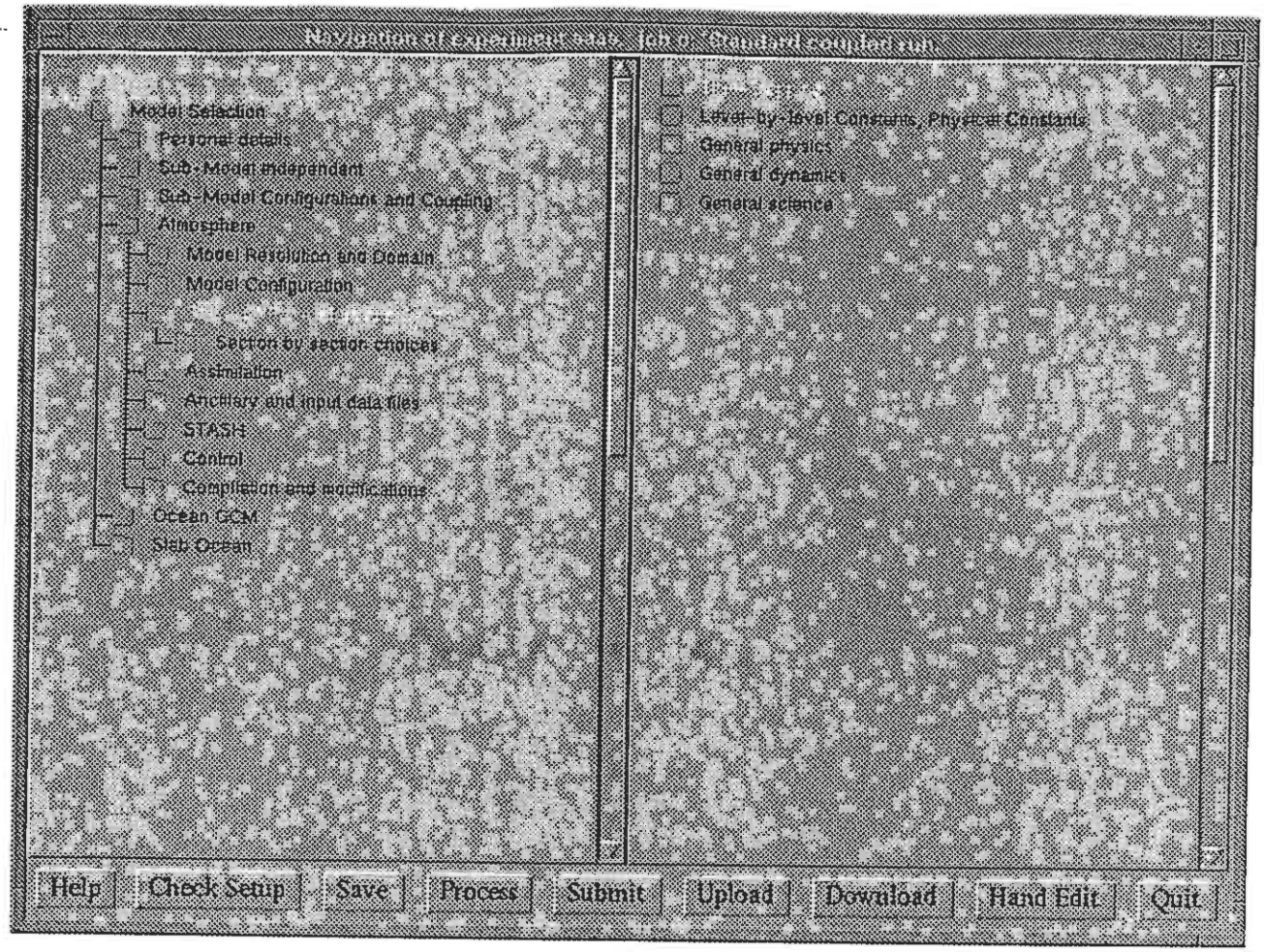

Figure 1.7: The main navigation window of the UMUI. Nodes in the tree (left) may be expanded and collapsed. In this example, the atmospheric model node is expanded. Selected nodes are opened up to display windows (right).

Using a central database that works in a distributed environment, the UMUI provides an efficient method of defining model runs and managing those definitions. A run definition is known as a job. Users can search for and copy jobs belonging to colleagues, and definitions can even be sent by email from one site to another. This allows colleagues and collaborators at remote sites to increase their efficiency by pooling their effort and knowledge. The job management system also provides help for users wanting to upgrade from one version of the Unified Model to another.

In addition to the job management system, the UMUI contains a comprehensive job definition system. This is an intelligent editor that allows modifications to be made to existing jobs. It is made up of a large number of windows, each with visual clues to ensure that users can quickly see when options have been disabled due to other responses. To further aid the user all windows have a help button that displays information relating to the options available on the window.

Once a job has been defined, the responses are translated into control files that can be read by the Unified Model. On request, the UMUI will then copy these to the target machine and submit the job. The control files are text based and so a user can easily over-ride the UMUI by editing the control files. This facilitates the prototyping of new features.

Reconfiguration

The reconfiguration module processes the model's initial data. It allows the horizontal or vertical resolution of the data to be changed or the creation of a limited area region (see figure 1.8). Ancillary data may also be incorporated into the initial data. Fields such as the specification of the height of orography or the land-sea mask, for example, may be overwritten by more appropriate values if the horizontal resolution has been changed. Other facilities available within the reconfiguration module include the ability to incorporate ensemble perturbations, tracer fields and the transplanting of prognostic data.

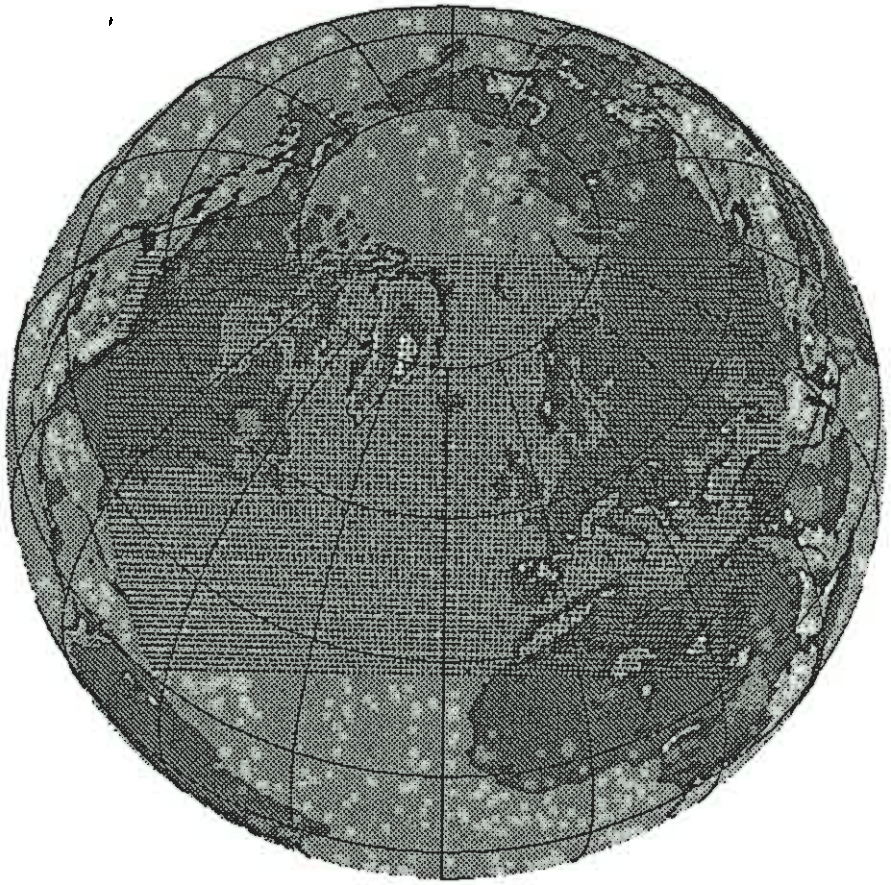

Figure 1.8: A regional integration domain and grid. Initial data may be interpolated onto such domains via the reconfiguration module.

Tracers

Both the atmospheric and oceanic components support the advection of passive tracers using a shape preserving advection scheme. The methods are designed to ensure that sharp gradients are preserved while keeping all concentrations greater than or equal to zero. This facility may be used to examine dispersion from point sources or as the basis for more involved chemical modelling by the addition of extra code. For example, atmospheric forecast configurations of the model include an aerosol variable which is advected using the tracer scheme, and may optionally have sources and sinks applied. This is used to estimate visibility, and may be adjusted by the assimilation of visibility data.

Ancillary Data

New ancillary data may be incorporated as an integration proceeds to allow for the effects of temporally varying quantities such as surface vegetation or snow cover. The choice of whether to include ancillary data will depend on the application. For example, the system supports daily updating of sea-surface temperatures based on climatological or analysed data - but this facility is not needed in coupled ocean-atmosphere runs of the model. In fact options exist to allow most boundary forcing variables to be predicted. However, it is often necessary to constrain such fields to observed or climatological values for reasons of computational economy or scientific expedience.

Diagnostic Processing

Diagnostic data output from the model may be defined and output on a timestep by timestep basis. Horizontal fields, sub-areas or timeseries may be be requested, along with the accumulation, time meaning or spatial meaning of fields. The output may also be split across a number of files in order to facilitate the separate post-processing of classes of diagnostics.

Output

The results of an integration are stored in a format compatible with other file types used within the Unified Model system. Several utilities exist which will convert them into a format suitable for further processing. These formats include GRIB - the WMO standard for storing fields of meteorological data in a machine independent format. Utilities to print out and compare the contents of Unified Model files are available. These, coupled with the bit reproducibility facility (see below), offer a powerful development and debugging aid.

Computer Requirements

The code was originally written in FORTRAN 77, but now uses a number of the extensions to the language available in FORTRAN 90. A small number of low-level service routines are written in ANSI C to facilitate portability. At the control level, the model runs under the Korn shell of the UNIX operating system. The model will normally require a powerful supercomputer for time critical production work. It is written to be efficient on shared memory vector supercomputers such as the Cray C90, but sections of the code have now been rewritten to allow running on distributed memory massively parallel processing (MPP) computers. The code is bit reproducible independently of the number of processing elements used. The code may also be run on workstation systems using the IEEE standard for representing floating point numbers. Workstations are particularly suited to development work or research activities requiring the use of low resolution configurations of the model.

1.1.6 The Future

Improvements to the scientific formulation and software capabilities of the Unified Model are always being sought and considered. A number of important developments are planned for the next few years:

- Major changes to the atmospheric prediction scheme which involve less approximation and improved methods of solution are under development. The non-hydrostatic form of the governing equations will be adopted, enabling the model to be used for very high resolution forecasting.

- The Unified Model system will move towards the use of variational methods of data assimilation. In this, a model state is constructed that is the best statistical fit to the observed data. A system like this requires a method of blending the observations with the background field provided by a simple linerized model which is integrated forwards and backwards in time to fit the observations to an evolving model state.

- The software infrastructure will be enhanced to allow the flexible incorporation of a range of environmental sub-models into the Unified Model system.

1.2 The History of the Unified Model

Author: Rick Rawlins, Last Updated: 15 Apr 96

1.2.1 Background to the Unified Model

By the end of the 1980's the Met.Office had developed separate numerical prediction models to sustain climate research and operational forecast capabilities. The climate model consisted of 11 vertical layers with a global domain at 250km horizontal resolution and incorporated a relatively sophisticated representation of physical processes. The operational model had 15 vertical layers and ran in two versions: a 'coarse mesh' global model at 150km resolution and a 'fine mesh' limited area model covering Europe and the N.Atlantic at 75km resolution. These models had simpler calculations of physical processes and employed a different dynamical integration scheme to that of the climate model. In addition a mesoscale model with 15km resolution provided some operational products for the UK area, and comprised a completely distinct formulation for both physics and dynamics. There were also new requirements arising from the need to include more complex interactions into long climate integrations, in particular the introduction of an ocean model, to be coupled explicitly with the atmosphere model.

Each model had its own control, file and output structure, as well as separate scientific formulations, with separate teams responsible for development. The models ran on a CDC CYBER 205 which was due to be replaced by an ETA systems platform during 1989. Significant effort was expended in adapting the code of each model to run on the new platform, but this work was suspended when the manufacturing company was wound up and a new vendor had to be found. It was decided to promote a longer term project to achieve a unification of model systems to fill the gap, and reduce the duplication of effort required to implement separate models on new hardware. The lifetime of the CYBER was extended and development of the CYBER models frozen; a Cray Systems YMP with 8 vector processors was procured with a unix based operating system and the machine arrived in January 1990. A formal Unified Model project was started in July 1989 and continued until October 1991 when it was judged that the main components were ready and the Unified Model was born.

A number of key strategic decisions has shaped the structure and development of the UM:

- The system would share a common control and file structure for all types of models, so that individual models running in separate environments would be replaced by different model configurations of the UM.
- Model set-up would be achieved via a graphical user interface, divorcing the detail of control file information from decisions made by the user. Thus presentation of model options to the user is simplified, the process of model submission is streamlined and the occurrence of inconsistencies or errors during set-up is reduced.
- The UM system would be upgraded periodically through change control management techniques, which is an essential safeguard for code changes made by developers that may affect other model configurations. Each upgrade constitutes a UM version.
- Model software would be coded in fortran, with a minimum of machine specific or low-level language additions. This is required to loosen the dependency on a particular hardware platform, and allow more rapid development of new scientific routines by researchers. This decision was later extended to include the objective of providing explicit portability. Hence model configurations which were developed on supercomputer platforms should be readily ported to other systems such as workstations, with a minimum of changes.
- Models would depend on a common output diagnostics system, which was capable of intercepting transient fields, or calculations based on such fields, as well as primary fields available through periodic model dumps.

- Separate choices of scientific schemes would be readily available from the user interface, and different physics schemes would be 'plug compatible', ie it should be easy to import or export schemes to other organisations' models with a minimum of effort.

1.2.2 Version upgrades and hardware platforms

Table 1.2 lists release dates for each UM version and the date at which the operational forecast model was upgraded to the new release. Some indication of the more major changes to the hardware platform is given.

UM Version	Release Date	Operational Release	Hardware Platform: Operating System	Compiler Release
2.0	16.05.91	05.06.91	Cray YMP-8: Unicos5.1	4.0.2
2.1	27.06.91	16.07.91		
2.2	15.08.91	17.09.91		
2.3	23.10.91	12.11.91		
2.4	07.01.92	11.02.91	Unicos6.0	
2.5	26.03.92	12.05.92		
2.6	04.06.92	11.08.92		5.0.2
2.7	01.09.92	27.10.92		5.0.3
2.8	22.12.92			
3.0	15.01.93	23.02.93		
3.1	30.03.93	25.05.93	Unicos7.0	
3.2	06.09.93	19.10.93		
3.3	03.06.94	12.07.94	Cray C90:	6.0.3.2
3.4	24.01.95	07.03.95		
3.5	03.08.95			
4.0	12.01.96	19.03.96		

Table 1.2: Unified Model Versions

The following sections illustrate the more significant changes that have contributed to version upgrades. Brief descriptions of system enhancements are given, with some indication of new scientific features, concentrating on the atmosphere model. In reality each UM version consists of a hundred or more individual changes, ranging from minor corrections to major improvements of infra-structure facilities, plus work required to take advantage of successive enhancements to the available computing resources.

1.2.3 Early versions 2.0-2.6

Rapid development continued to consolidate the performance of the UM. A significant number of error corrections arose from the relative immaturity of the code. Changes included:

- Introduction of C I/O routines to replace Cray specific unblocked data files and replacement of reference to file names by assign statements to being passed by environment variables.
- Source code modification of code by users for compilation was changed from "quick" to "normal" modes of Cray proprietary update package, to ensure that a change to a COMDECK was propagated to all affected routines (see section 3.19).
- Vertical interpolation of boundary files was enabled, allowing generation of boundary conditions for a model on a different vertical grid.

- A facility to enable timeseries to be output from the diagnostic system was introduced.
- The conversion of potential temperature to temperature ($\theta \rightarrow T$) was modified to account for the dynamical formulation of the hydrostatic relation; definitions of standard vertical hybrid co-ordinates changed.
- Dynamics calculations at the top model level could now be switched to run with a halved timestep, preventing model instabilities causing model failures without the cost of running the entire model with a reduced timestep.

1.2.4 Version 2.7

Changes already available through the UM system were co-ordinated to produce a UM mesoscale configuration with 30 vertical levels. This replaced the earlier mesoscale model and went operational in December 1992.

- Several enhancements of physics were consolidated in the system, including the components contributing to the first climate version (1CV, now labelled HADAM1):
  1. Convection with an explicit downdraught;
  2. Rapidly mixed boundary layer code.
- Introduction of a separate version of the longwave radiation scheme based on transmissivity values derived at ECMWF.

1.2.5 Version 2.8

- Upgrade of source code management tool from Cray update to Cray nupdate.
- A new packing code was introduced into look-up headers of data fields to cater for new combinations of packing and data compression. This required an explicit utility to convert model dumps at 2.7 and earlier to the new format at 2.8.
- (Outstanding 1CV science change): grouping of model levels into 3 explicit cloud layers within the shortwave radiation scheme.
- Time-smoothing during the adjustment timestep within the dynamics was introduced to alleviate the problem of noisy fields at upper levels in the operational global model.

1.2.6 Version 3.0

The active code of Version 3.0 was identical in content to that at 2.8, but line numbers of code were resequenced and some old comments were removed. DECK names were changed systematically to reflect the concept of multiple version-releases of a code section (see section 3.11).

1.2.7 Version 3.1

- A new option was provided to allow more than one boundary file to be produced by the model, so that multiple limited area models could be driven from the same generating run.
- Functionality of the reconfiguration program was extended to include initialisation of model analyses with ECMWF perturbations, simplifying running of this category of ensemble forecasts. An option to transplant fields from a different model dump into a given domain within the model analysis was also developed.

1.2.8 Version 3.2

The first version of the portable model was made to work at 3.2 on HP workstations, but with a large number of local modifications, and relied on fixed experiment libraries generated by the user interface on the IBM mainframe computer.

- Dynamic allocation of primary fields was introduced and required large scale changes to the top level control structure of the model. Sizes of arrays depending on the model configuration were now passed at run-time, removing the necessity to re-compile when changes in diagnostic output were required.
- The value of the real missing data indicator was changed from -32768.0 to -2**30 to reduce the possibility of valid data being assigned as missing.

1.2.9 Version 3.3

- A facility for users to introduce their own prognostic variables without requiring a change to the user interface was implemented, giving code developers freedom to make and test a greater range of modifications locally.
- GRIB format for output fields was provided as an option. The file structure was of hybrid form, with lookup headers retained, but data packed as GRIB.
- A halving of the dynamics timestep could be initiated on an automatic basis, depending on thresholds of wind speed or divergence in the top level being exceeded.
- Calling convection routines less frequently than every timestep was enabled, providing a method of reducing cpu costs of the operational mesoscale model without significant degradation in performance.
- The provision of source terms for aerosols, as part of a tracer advection technique for dealing with passive variables, provided essential functionality for both climate studies and later mesoscale visibility calculations.

1.2.10 Version 3.4

- Unix scripts in the UM system were brought within code management by nupdate as part of change control for new versions. This replaced having single frozen copies and simplified the action of modifying scripts by different people.
- Macrotasking techniques were introduced into dynamics, convection and radiation schemes to facilitate more efficient use of the multi-tasked C90 environment.

- New options for atmosphere science routines, constituting the main components of the second climate version (2CV, now labelled HADAM2a):
  1. A more complex treatment of orographic roughness within the boundary layer code, including the representation of silhouette orographic roughness;
  2. A new gravity wave drag scheme incorporating anisotropic directional orographic variances and 'hydraulic jump' terms;
  3. A new version of the convection routine with excess parcel buoyancy generated from the surface level fluctuations of temperature and humidity;
  4. A new large scale precipitation scheme with all snow falling out in a layer in the same manner as for rain;
  5. Inclusion of primitive cloud microphysics within the shortwave radiation scheme, allowing a variation in cloud effective radius;
  6. An option to re-set negative humidity values locally rather than globally.
- A new multi-layer soil hydrology scheme.
- Inclusion of trace gases in a new version of the longwave radiation.
- Assimilation of humidity from MOPS (Moisture Observation Pre-processing System) was introduced, providing a method of feeding moisture information back into the hydrology cycle of the operational mesoscale model.
- A dynamical sea-ice model was included in the Slab model (see section 3.14).
- An ice section was added to the ocean model and assimilation within the ocean model enabled.
- This version was released to a number of external users, now with the capability of running on a Dec Alpha workstation.

1.2.11 Version 3.5/4.0

3.5 was an interim version required to stage the large changes planned for 4.0, and only had significance for the core development and testing team. This version spanned the transfer of central UM system facilities, including the user interface, from the IBM mainframe to a more portable unix environment. At the Met. Office this consists of a combination of HP workstation local area networks with the Cray C90. Modifications to code for 3.5 relative to the previous version were located on the mainframe. The repository for modifications to code against 3.5 and later versions is the Cray C90. Development of a new graphical user interface, the UMUI, was partially completed at 3.5, and fully implemented for 4.0. Submission of model jobs to the Cray C90, and inspection of subsequent output listings, was made independent of the IBM mainframe.

- An X-windows user interface (UMUI) based on public domain TCL/TK building tools was produced, a completely new program and structure from the mainframe interface designed at the beginning of the UM. The UMUI now resides on HP workstation networks, and is capable of being ported to other machines, such as the Cray C90 itself. This provided a more flexible platform for initiating experiment set-up within the Met. Office and created the capability to package up the entire UM system for implementation by external users.
- The first stage of work to facilitate the introduction and coupling of new sub-models into the system was completed. This included the transfer of primary addressing calculations, which had been performed pre-3.5 by the user interface on the mainframe, into the model initialisation. In addition a new paradigm of sub-models and internal models was introduced for dealing with different combinations of sub-model types.

- Provision of the capability of running with a long physics timestep enabled significant reductions in cpu costs to be achieved by reducing the number of physics calculations while maintaining model numerical stability.

- Adoption of the UMUI running on HP workstations led to a loss of bit reproducibility for models set up at 3.4 and 4.0 due to the change in precision of floating point calculations now performed on the 64 bit Cray machine rather than the 32 bit IBM; and also due to the difference in number representation from IBM to HP. Other minor changes were made that also affected bit reproducibility:

  1. Correction in the value of π;
  2. Corrections to filtering within the dynamics.

- Addition of science routines to constitute third climate physics (3CV, now labelled HADAM2b):

  1. Precipitation changes: Improved mixed phase and evaporation calculations; explicit flux divergence and flux equilibrium schemes for ice fallout dependent on timestep;
  2. Re-appraisal of saturated specific humidity formulation.

- A new radiation scheme (Slingo-Edwards) was introduced, covering both longwave and shortwave regions, providing a greater flexibility of choice of radiative spectral intervals.

- A new hydrology routine incorporating the Penman-Monteith scheme was added, with consistent changes made to a new version of the boundary layer routine.

- Optional removal of horizontal diffusion for sloping model levels was included.

- Latent heat nudging in the assimilation was provided for investigations with the operational mesoscale model.

- Copyright notices were added to each item of source code.

Chapter 2

Understanding the Unified Model

This chapter will contain information on various aspects of Numerical Weather Prediction and the Unified Model. Unfortunately this information is not yet available.

Chapter 3

Using the Unified Model

3.1 The Unified Model User Interface (UMUI)

Author: Mick Carter, Last Updated: 4 Apr 96

This section is aimed at new users of the UMUI and gives basic instructions concerning its operation. Note, however, that most of the documentation for use of the UMUI is in the form of help windows within the UMUI.

3.1.1 What is the UMUI

The UMUI is the Unified Model User Interface. It is a tool to help people set up and manage a number of runs of the Unified Model (UM).

The UMUI is built using a tool called the Graphical Hierachical User Interface (GHUI). This tool enables user interfaces such as this to be built with ease. The GHUI is written using Tcl/Tk and C code.

3.1.2 Reporting Problems

Met Office Users

Please report any minor problems with the UMUI system to the newsgroup:
`ukmo.met.um.umui-bugs`

Or, by mailing to:
`umui@hadl30`

For larger problems, ie those that may affect other users, please cross post to the UM newsgroup:
`ukmo.met.um`

External Users

Mail to:
`mjcarter@meto.govt.uk`

3.1.3 Kicking off the UMUI

To start up the UMUI on most systems, just type:
`$ umui`
on a terminal, xterm or console window. If you do not want to lose the ability to use the terminal window, type:
`$ umui &`
Installations at other sites may have other additional methods of starting the UMUI, such as tool-bar icons. Also, it is possible that you may need to amend your PATH to pick up the UMUI. See the relevant local person for advice.

You will now have entered the experiment table. You may need to kill off other processes that are interfering with the colour table. In particular, *Netscape* uses a lot of colours, you are advised to use it in mono-mode or reduced colour mode:
`$ netscape -mono &$ netscape -ncols 20 &`

Check that you are not using any facilities that need a lot of colour and start the UMUI now.

3.1.4 Migrating from the old, MVS-based, User Interface

This information is for those users who have had access the the previous version on the User Interface that runs on the MVS-based computer at the Met.Office.

The first thing to note is that there are no tools for migrating jobs from the old User Interface to the UMUI. The second think to note is that the system is quite different, and you should take time to read this introduction and the help. Most users are finding the new system better and easier to use.

3.1.5 The Constituent Parts of the UMUI

The Entry System

Having started the UMUI, you will now be in the entry system. You should now read the introductory help from this part of the system:

- *Introduction to the UMUI:* Gives an overview of the UMUI and its component parts.
- *Introduction to the UMUI entry system:* Gives an overview of the entry window and its layout.
- Specific help is available for each of the functions in the entry system. You should read these carefully, go and do this now. Use the left mouse button to interact with the drop down menus.

You should now know how to find, create, copy and "open" jobs, and organise them into experiments. Opening a job will take you on to the navigation system, described below.

The Navigation System

This window allows you to find entry-windows (displayed on the right) by moving around a "navigation tree" (displayed on the left), and to do things like save changes and process jobs (using buttons at the bottom).

You should now read the help windows on the navigation system:

- *The navigation system:* Gives an overview of the navigation and its component parts.
- Specific help is available for each of the functions in the navigation system. You should read these carefully, go and do this now.

Entry Windows

The navigation system helps you get to what are called *Entry Windows*. These allow you to change the settings that define a run of the Unified Model. They are described in the help from the navigation system. STASH uses non-standard windows and has its own help.

- *Entry Windows:* Gives an overview of how standard entry windows work.
- *STASH Windows:* Gives an overview of how the non-standard STASH windows work. There are other help windows for STASH that should be read before using this part of the system.
- Specific help is available for each entry window. You should read these as you explore the system. Look at some now.

3.1.6 Common Pitfalls

Users of the previous MVS based user-interface may be tempted to think that experience will just transfer across from using the old system. This is not the case, and here is a list of common pit-falls that you may find:

- **Losing files:** Do not put temporary files in the job library. They will be deleted when the job is processed.
- **Personal Details:** Do not forget to change the personal details information for copied experiments.
- **Directories:** Do not use environment variables (eg DATAW) directly, use $DATAW etc. You can use any environment variable available to your job, and now you can set up several.
- **User-STASHmaster files:** Remove any LEADING zeros from integer entries except the Option Code and Version Mask.
- **Unset variable:** The processing program may fail because you have not set a variable. In this case you may get a message in an error window. Such problems can be fixed by using the Check-Setup option avaiable from the navigation window. This will provide a path to the window with errors.
- **Tables:** Tables need to be filled in with great care. Use the mouse and cursor keys rather than TAB. While TAB can be used for moving between entry boxes, it will not work in tables. You can also cut and paste between boxes in tables to help speed things up. Please note that when Caps Lock is set, you will not be able to work scroll bars with the mouse. However, Y or N entries can be filled in using upper or lower case; the UMUI will convert them to upper case when you close the window.
- **Open jobs:** Do not forget to close your UMUI session before logging off. If you forget, your job will stay open and you will not be allowed to open it read/write. You will then need to force the job closed using the option in the job menu of the entry system.

- **System Crashes:** Periodically save during long sessions defining a job. There is no automatic backup taken. As above, if a crash occurs while a job is open, you will need to force it closed before you can edit it.
- **STASH windows:** The STASH windows are non-standard in the UMUI and quite different from the old UI. You should:
  - **Read all the help.**
  - Enter STASH windows last for each sub-model.
  - Only open 1 STASH window at once.
  - Remember **not** to type into the table on the main window. Use the mouse to add profiles to the diagnostic table. All edits are lost.
  - Remember that checking the STASH setup is **not** done automatically. You must do this yourself.
  - Close STASH before processing, saving or using any of the other navigation buttons.

3.1.7 Submitting Jobs

Now that you have defined your job through the entry windows, avoiding the pitfalls, you will want to submit the job.

Before you start

You will need a `.rhosts` file on the target machine (where the model will run). The access permissions of this file need to be correct; you cannot give other users write or execute access. You need to list all "servers" that you may use.

On the Cray C90 type eg:

```
$ cat > .rhosts << EOF
>machine1 hadmk
>machine2 hadmk
>machine3 hadmk
>machine4 hadmk
>EOF
$ chmod 644 .rhosts
```

Where machine1, etc is a list of the "servers" that you tend to use. The UNIX command `hostname` will tell you the name of the machine you are currently using.

You may also need a `.redirects` file in your output directory if you are asking for your output to be archived or sent to a particular destination on your work-station. See below for more information about output.

The submit sequence

You should follow this sequence of events:

- **Define the job:** The definition of the job should have been finalised by setting the required values through the UMUI windows.

- **Check Setup:** Checks that everything is consistent.
- **Save:** Saves your changes back to the database.
- **Process:** Processes your job definition into control files suitable for use by the UM.
- **Edit your job:** The process step will create a job directory containing the control files, it will tell you where the directory is. You may wish to hand edit the control files. This is NOT the purpose of the *Hand Edit* button on the navigation window:
  - **Hand Edit:** For Hand editing the database file for this job, *not the control files.*
- **Create any Files and Directories you require:** You may need to copy a dump into place or create your `$DATAW` or `$DATAM` directory before you can submit your job.
- **Submit:** Submit the job. If the UMUI is down, and you want to submit a job, you can use the facility *umsubmit* from a terminal window as follows.
  Type:

```
$ umsubmit [-h host] [-u user_id] job_name
   -h host      Name of host machine. Default is c90.
   -u user_id   User id on host machine. Default is the
                user id returned by the ibmproxy command.
```

What then?

Once submitted, all the files are copied to the target machine and you can do what you like with the job files created by the UMUI. *You can edit them without worrying that the running job will pick up the wrong version.*

You will see a new directory on the Cray called umui_runs. This will hold the copies of your control files until the job starts running. Once the job has run, all files should be deleted and the sub-directory (e.g. `umui_runs/aaaka_$DATE_$TIME`) should be removed. It is a good idea to tidy this directory up periodically.

Browsing your output

The output is to be found in your output directory `$MY_OUTPUT` on the target machine. The file name is:
`$JOBNAME[$COUNT].$RUNID.$DATE.$TIME.$ACTION`
The directory may vary at your site. Seek local advice.

- `$JOBNAME`: Is the job-name defined through the UMUI by the user.
- `$COUNT`: Optional. Is used when jobs are automatically re-submitted.
- `$RUNID`: Is the RUNID (`$EXPID$RUNID`) of the job.
- `$DATE`: Is a date stamp `d{%y%j}`.
- `$Time`: Is a time stamp `t{%H%M%S}`.
- `$ACTION`: Is the optional action defined by the user. The server will perform the action defined, such as send to fiche, archive, etc.

You can view other peoples output by looking at the target machine directory `$JOB_OUTPUT`. This also contains a README file defining how to set up `.redirects` files for some of the action options. Again, the directory and details will vary at individual UM sites.

You can view the output directly on the target machine using `pg` or `more`. If the target machine is a Cray there is a browser that can be used, eg:

```
sn4023$ DISPLAY=hc0303:0;export DISPLAY
sn4023$ xbrowse H20MKE01.aaaee.d96011.t111020.leave
```

This is an x-windows browser that is quite easy to use. Set and save the options, preferences for full text display and the vi editor. Switch everything else off. The find window is available from the view menu (not find!).

It may be possible that the files are also cross mounted onto your local work-station systems. Seek local advice. You should take care not to use editors, such as `vi` and `ved`, on these files if they are very large as it will cause a lot of network traffic.

3.2 Standard Experiments

Author: Richard T.H. Barnes, Last Updated: 29 Mar 96

3.2.1 Introduction

Setting up a new Unified Model experiment from scratch is a daunting task, since the UMUI (see section 3.1) has some 250 windows but *no defaults*. Often you will be able to copy an experiment which nearly does what you want from a colleague (or yourself) and modify your copy. A useful alternative starting point is the set of standard experiments.

For portable model users, the package contains standard global climate, LAM and mesoscale jobs. Accompanying documentation will give details.

For internal Met. Office users, standard jobs for the operational atmosphere configurations exist. Locations of current standard jobs are given on the Met. Office Web at URL: http://fr0800/umdoc/hestanexpt.html. As each new version is released, 3 standard forecast experiments, based on those to be introduced operationally, are set up. These cover global, LAM and mesoscale configurations. They contain jobs set up:

- with operational domain, grid-length, levels for global, LAM or mesoscale
- with appropriate physics versions, diffusion, assimilation
- without output for wave models, MOS, job release, archiving
- with a small sample set of STASH output
- to run from a particular set of current operational data files.

There may be more than one job under a particular experiment, particularly if there have been major upgrades during the operational lifetime of a UM version. To find out more about each job, read the 'Description' of the jobs within the experiment. Other users' jobs can be browsed in full in 'read only' mode under the UMUI. There is a comprehensive set of search criteria under 'Find' - 'Filter...'.

3.2.2 Copying a Standard Experiment

To make a copy of a job, first create a new 'Experiment' for yourself or highlight one of your existing experiments. Then also highlight the job you wish to copy. Click on 'Job' and then 'Copy' and select a letter free in your experiment file.

So that all experiments are available across all systems, the 'basis' file for each job is held centrally and is not available to users. However, when you save and process your job, a directory is created on your file system with the name:
`$HOME/umui_jobs/exptj`
where

- `$HOME` is your HP home directory
- `expt` is the unique 4 character experiment id
- `j` is the job letter within the expt

This directory contains the UNIX script `SCRIPT` which is submitted to run your forecast job, and all the control files required by the job.

Reminder: whenever a job is processed, its umui_jobs/exptj directory is totally cleared and rewritten - you cannot store hand-edited files in these directories.

Once the job is copied, make sure you unhighlight your experiment and the job you were copying from before trying to open your new job and start working with it, as the UMUI will try and open anything that's highlighted all at once.

On first entering a copied job, remember to select window **personal_gen**
`Personal details`
`-> General details`
and alter userid, jobname, etc. to yours.

3.2.3 Warnings

When you have set up a new experiment, **test it with a short run** (but long enough to cover all important features, eg. STASH output or ancillary updating) and check the output, before you commit yourself to using large amounts of computer time for your full runs.

Given the complexities of the Unified Model, it is really not possible to provide a standard experiment for you simply to copy and run, without any input by the user. You must think about what you want from your experiment:

- length of forecast
- STASH output
- job resources
- order and coefficients of diffusion (if you change grid length)
- initial data, boundary conditions (for limited area)
- ancillary files and/or observations (if any)
- etc.

Details of how to modify these are given in other User Guide chapters on control changes (section 3.4) and changing resolution (section 3.8).

3.3 Simple Tutorial

Author: Richard T.H. Barnes, Last Updated: 11 Apr 96

The purpose of this section is to introduce you to using the UMUI by taking you through the windows that you really ought to view, even if just having a first try at running a copy of a standard job. Section 3.4 (control changes) covers other windows you are likely to use as you become more experienced.

Having created a NEW job, probably by copying a standard one, the first window to use is **personal_gen**
`Personal details`
`-> General details`
Tailor this to your personal and machine specific requirements. Notice that, depending on your selection of "submission method", one of the following sections will be 'greyed out' because it is not relevant - this occurs in many windows. Again depending on your "submission method", you will need to make some decisions about job resources. Note that every window has at least "Help", "Abandon changes"=values not altered, and "Close"=values accepted and altered if changed (invalid answers will trigger warning/error windows). Windows cannot be closed with invalid answers. Clicking on "Help" will give you extra information about the questions in that window.

Clicking on
`Sub-Model Independent`
gives many window choices in the right half of the Navigation window plus a number of new sub-sections in the left half. This illustrates the typical behaviour of the Navigation window.

Of these windows available under Sub-Model Independent, **subindep_FileDir**
`Sub-Model Independent`
`-> File and Directory Naming`
is important for specifying the directories most of your input files will be read from and your output files written to. Customise this to your requirements and your machine's conventions. Of the "time convention options", "relative time" should be used for forecast runs, while "absolute time, standard convention" is used for long climate runs.

subindep_Runlen
`Sub-Model Independent`
`-> Start Date and Run Length Options`
is a key window where you must give the date/time of your start dump file (this will be checked against values held in the dump header - except for assimilation runs), and the target length of your forecast run.

The section
`Sub-Model Configurations and Coupling`
can be ignored, unless you are running coupled models.

Everything that needs to be set to specify completely the characteristics of the model to be used in your run can be found under its appropriate sub-model. For instance, clicking on
`Atmosphere`
gives several sub-sections. Detailed descriptions are given in section 3.4 (control changes) and elsewhere in the User Guide. Copies of standard jobs should have sensible answers in all these windows. However, only a small selection of diagnostic output is normally included in standard jobs. Read section 3.16 (STASH) to see how to choose new diagnostics.

To run your job, just click in turn on "Save", "Process" and "Submit".

Note that he values you have entered are not saved in the UMUI central database until you "Save".

"Process" creates or rewrites a directory under `$HOME/umui_jobs` containing a unix `SCRIPT` and all the control files required to run your job.

If "Submit" does not work, it may be that you need to set up a `.rhosts` file on the target machine.

3.4 Control Changes

Author: Richard T.H. Barnes, Last Updated: 11 Apr 96

The purpose of this section is to increase your knowledge of the UMUI by discussing some of the windows you are likely to use as you become more experienced. The simple tutorial section (3.3) covers some of the most basic windows, and they will not be repeated here.

To make the navigation easy, I will discuss the windows in top-down order and will keep to general (Sub-Model Independent) and atmosphere windows as the other sub-models are similar.

Window: **subindep_Compile**
`Sub-Model Independent`
`-> Sub-Model Independent Compile options for the model`
For your first run, you will normally need to compile and build an executable and then run. If you create this in a permanent directory (not `$TEMP`), you can, if you want, here choose to use this, or any other existing, executable for further runs, thus saving the cost of recompiling the same code. Other choices in this window depend on whether you are running on a conventional, vector or massively parallel machine - "Help" gives more information.

Window: **subindep_JobRes**
`Sub-Model Independent`
`-> Job resources and re-submission pattern`
lets you specify qsub job resources. Note that these are the same questions as in window **personal_gen**
`Personal details`
`-> General details`
There are several cases of the same question being present in more than one window, but there is only ever one value (the latest specified) held in the job basis file. Job output treatment is UK Met. Office specific, and automatic job re-submission is mainly used for long climate runs.

Everything that needs to be set to specify completely the characteristics of the model to be used in your run can be found under its appropriate sub-model. For instance, clicking on
`Atmosphere`
gives a number of sub-sections. Detailed descriptions are given here or elsewhere in the User Guide.

The section
`Atmosphere`
`-> Model Resolution and Domain`
should be set up OK for standard jobs. If you need to alter these, read the sections on changing resolution (3.8) and selecting a new LAM area (3.9).

The section
`Atmosphere`
`-> Model Configuration`
should be OK - but note that the total aerosol fields questions in the window **atmos_Config_Prognos**
`Atmosphere`
`-> Model Configuration`
`--> Prognostic variable choices`
are at present only appropriate for detailed studies of visibility over the UK mesoscale model area.

Some of the windows under
`Atmosphere`
`-> Scientific Parameters and Sections`
will need to be selected if you decide to change resolution (see section 3.8), while for many of the windows under

`Atmosphere`
`-> Scientific Parameters and Sections`
`--> Section by section choices`
there are different versions of model code sections available - again "Help" provides advice on these choices. However, the given standard jobs should all have suitable settings.

Unless you are running a model with assimilation of observations, the section
`Atmosphere`
`-> Assimilation`
will be irrelevant, with "No Assimilation" set in the window **atmos Assim General**
`Atmosphere`
`-> Assimilation`
`--> Parameters, Control`
To use assimilation you will need access to suitable acobs files. There is a separate section giving details of assimilation (3.5).

The section
`Atmosphere`
`-> Ancillary and input data files`
is a large section with several further sub-sections to explore, though standard jobs should have everything set correctly if the pathnames of your start dump and any ancillary files agree with those specified in the appropriate windows. There is a separate section giving details of ancillary and boundary files (3.6).

The section
`Atmosphere`
`-> STASH`
which controls diagnostic output requests, is probably the biggest and most complicated section to set up. See section 3.16 on diagnostic output (STASH) for details. The standard jobs contain just a few typical diagnostic requests to give a flavour of what is possible.

The section
`Atmosphere`
`-> Control`
is the general term covering a number of sub-sections which don't obviously fit anywhere else. These should all be set up in standard jobs, but include such things as model dump frequencies and the control of climate mean diagnostics (see section 3.17), diagnostics to check on sensible model evolution, and outputting lateral boundary conditions for Limited Area Models (details of this are given in section 3.9 on selecting a new LAM area).

The section
`Atmosphere`
`-> Compilation and modifications`
is where you can control "Compiler Options" which can be useful for debugging, and where you can add user written source code modifications (in UPDATE format, see section 3.19).

When you want to run your job, just click in turn on "Check Setup", "Save", "Process" and "Submit".

The "Check Setup" option performs comprehensive cross checking and searches for unanswered questions within the chosen sub-model(s).

The values you have entered are not saved in the UMUI central database until you "Save".

"Process" creates or rewrites a directory under `$HOME/umui_jobs` containing a unix `SCRIPT` and all the control files required to run your job.

If "Submit" does not work, it may be that you need to set up a `.rhosts` file on the target machine.

3.5 Assimilation

Author: Stuart Bell, Last Updated: 13 Feb 96

3.5.1 Introduction

The data assimilation scheme adjusts the model state towards observations, providing initial fields for forecasts. Observational data is assimilated by an iterative or "nudging" procedure which is carried out at each timestep of a separate model integration preceding the analysis time. This technique is referred to as the Analysis Correction scheme. The analysis increments required to nudge the model state towards the observations are computed from the observational increments, weighted by a factor depending on their displacement in space and time, and on the observational density and error. Additional balancing increments are also calculated.

In brief, we start with an analysis and one or more observation files valid for a period beyond the starting analysis and we end with an analysis valid at the time of the last batch of observation. The UM may then continue to run beyond the end of the assimilation period in forecast only mode.

For those who need more than just the basic knowledge of the analysis correction assimilation process, I direct you to the UM documentation papers:

- UMDP 30: Analysis Correction Data Assimilation scheme [7]
- UMDP P3: Technical Details of the Unified Model Data Assimilation System [25]

This technical documentation is essential if you need to run anything more than the default configuration.

3.5.2 The Observations

Observations are obtained from the Observation Processing system (OPS). These are often called ACOBS files. They are tailored to the required UM configuration. Each ACOBS file contains all the observations within a time window (usually 6 hours for global and 3 hours for limited area configurations) which are required for the assimilation. The observations within an ACOBS file are grouped into types. These AC_OBS_TYPES (see section 3.5.3) can be selected via the appropriate UMUI panel as desired.

The operational ACOBS files are available in the operational 18 month archive. Alternatively the observation processing system may be rerun taking unprocessed observations from the SDB/MetDB archive and a background (T+3 or T+6) fieldsfile from a UM run at the desired configuration. Within the Met Office, the COSMOS Obs User Interface (see [29]) can be used to restore from the archive or rerun the OPS.

The following documents cover the OPS in more detail:

- UMDP P51: Observation Processing for the Unified Model: Technical Documentation [26]
- UMDP P52: Quality Control of Atmospheric Data - Technical Documentation [27]
- UMDP 31: Observation Processing for the Atmospheric Model [8]
- UMDP 32: Quality Control of Atmospheric Data [9]

3.5.3 AC Observation Type Numbers

P*

- 101: Pressure at model surface

Potential Temperature

- 201: Radiosondes, on model levels
- 202: Surface Temperature from Ships
- 203: Single, upper level temperatures (aireps)
- 204: Surface Temperature from Synops
- 205: LASS or GLOSS (satellite soundings processed in-house)
- 206: Layer mean temperatures from 500km Satems
- 207: Layer mean temperatures from 120km Satems
- 208: LASS or GLOSS with first guess temperatures
- 209: CFO Bogus thickness (1000-500mb) observations (processed as layer mean virtual potential temperature)
- 211: UARS Temperatures

Winds

- 301: Radiosondes, on model levels
- 302: Surface Winds from Ships
- 303: Single, upper level winds (aireps, satobs and CFO bogus)
- 304: Surface Winds from Synops
- 305: Surface Winds from the ERS-1 Scatterometer (SCATWINDS)
- 306: Surface Winds from Buoys
- 311: UARS Winds

Relative Humidity (RH)

- 401: Radiosondes, on model (wet) levels
- 402: Surface RH from Ships
- 403: Single, upper level RH (CFO Bogus observations)
- 404: Surface RH from Synops
- 405: LASS (No code available to process this type yet)
- 406: RH from MOPS
- 407: AVHRR cloud histograms

MOPS

- 506: MOPS rain

UARS Chemical Data

AC Observation Types 601-629 are reserved for various chemical tracers observed by UARS.

Surface Visibility

- 901: Surface Visibility

3.5.4 Relevant UMUI Details

At build 4.0, the panels relating to the assimilation contain references to the variational analysis options. Please ignore all these references. We don't anticipate releasing the 3DVAR system before end-1996. The following panels are the ones relating to assimilation with the most convenient route given. There are full help options within the UMUI so only a brief commentary is given here.

1. Window: **subindep_Runlen**
   `Sub-Model Independent`
   `-> Start Date and Run Length Options`
   The run time should be the SUM of the assimilation period and any subsequent forecast period. When starting in assimilation mode, the start date/time may be set to 0.

2. Window: **atmos_Assim_General**
   `Atmosphere`
   `-> Assimilation`
   `--> Parameters, Control`
   Select version 1A and run in Analysis Correction mode with Standard macro. The assimilation time details (hours after basis time) are specified as follows:

Start	= x,	usually x=0
End	= y,	y=z+4 for global (z+2 for LAM)
Nominal analysis time	= z,	z=(obs window)*(no. of obs windows beyond start)

   A few general options about the character may be specified, particular those dependent on the configuration. For the experts, many detailed tuning option can be made available by providing an additional namelist details, taking guidance from UMDP P3 (see [25]).

3. Window: **atmos_Assim_Obs**
   `Atmosphere`
   `-> Assimilation`
   `--> Observation choices`
   This panel allows the user to choose the AC_OBS_TYPES (see section 3.5.3) required (presuming of course that they were included in the ACOBS file when the OPS was run). The observations are grouped together during the assimilation stage. This grouping is flexible but it is anticipated that nearly all users will wish to group as in the operational configuration. The crib in column 2 (GLMS) indicates the operational groupings (a '.' implies the observations are not used in a particular configuration; G=global,L=limited area,M=mesoscale and S=stratospheric).

4. Window: **atmos_Assim_DivDamp**
   Atmosphere
   -> Assimilation
   --> Divergence damping in the assimilation
   Appropriate divergence damping coefficients should be set for assimilation mode (resolution dependent values usually mirror those used operationally which are given in the UMUI help panel).

5. Window: **atmos_Science_Section_Dassim**
   Atmosphere
   -> Assimilation
   --> Data assimilation, section choice
   This is also set within window **atmos_Assim_General**. Use version 1A of the assimilation code.

6. Window: **atmos_InFiles_ObsData_ACObs**
   Atmosphere
   -> Assimilation
   --> ACOBS data
   Specify the path of the observation files, up to a maximum of 10. Usually one more file is required than the number of observation windows up to the analysis time (the extra file covering the period around the start analysis time.

7. Window: **atmos_STASH_Macros_BackG**
   Atmosphere
   -> STASH
   --> STASH Macros
   ---> Background quality control macro
   Click standard macro to specify that a background fieldsfile is required for use by the OPS in a subsequent cycle. It is not relevant for single cycle runs.

8. Window: **atmos_STASH_Macros_Assim**
   Atmosphere
   -> STASH
   --> STASH Macros
   ---> Internal assimilation macro
   This is also set within window **atmos_Assim_General**. Click standard macro if running an assimilation to make non prognostic variables available to the assimilation during the model run.

9. Window: **atmos_STASH_Macros_MOPS**
   Atmosphere
   -> STASH
   --> STASH Macros
   ---> MOPS output macro
   Click standard macro if you intend to process MOPS data in a follow-on cycle. This is unlikely outside the operational environment.

3.6 Ancillary and Boundary Files

Author: Richard T.H. Barnes / David Robinson, Last Updated: 11 Apr 96

3.6.1 Introduction

What is an ancillary field? This is not as straightforward as it seems, because whether a particular field is an ancillary field depends on the context in which it is used in a given configuration of the Unified Model. One possible definition is:

> A prescribed "prognostic" variable held in a model dump, which may be updated during a UM run (with appropriate time interpolation) by values read from an external ancillary file.

For example, snow depth is an ancillary field if it is imposed and either held constant or updated from an ancillary file, but if (as is permissible) its value is allowed to be predicted by the model's precipitation and hydrology schemes it is not an ancillary field.

Some fields, such as orography and the parameters which classify soil and vegetation characteristics, are at present ancillaries in all circumstances. However, introduction of, for instance, a scheme for interactive vegetation would change this.

How is an ancillary field got into a UM run? There are 3 basic ways:

- It may be in your initial dump already. If so it will be interpolated if the dump is reconfigured (see section 3.7) to a new resolution and/or domain. Do you want this?
- It may be replaced in your initial dump by configuring in from an ancillary file on the correct domain and resolution.
- It may be added to your initial dump as a new ancillary field by configuring in from an ancillary file on the correct domain and resolution.

Details of these procedures can be found in section 3.6.4

Some comments on boundary updating files, which are essentially a special form of ancillary file, will be given in section 3.6.6.

3.6.2 Location of standard ancillary files

Ancillary files exist for each standard Unified Model domain and are available for general use. Most of these files have been interpolated from raw data at 1 degree resolution, though those for orography and land/sea mask are from global 10 minute data or higher resolution data for certain parts on the world. For a full list of files and data sources see UMDP 70 [17]. At the UK Met. Office all the files are stored on the Cray C90 supercomputer in a directory structure of the form:

$UMDIR/vn*n.m*/ancil/*submodel/domain*/qr*type.data.suffix*

- $UMDIR (= /u/um1 on the Cray C90) is the Unified Model 'home' directory
- *n.m* is Unified Model version number
- *submodel* is one of atmos, ocean, etc.

- *domain* is one of the standard model domains, thus:
  - cl_9673 for 96x73 grid points climate model,
  - gl_288217 for 288x217 grid points operational global model,
  - la_229132 for 229x132 grid points operational Limited Area Model,
  - ms_9292_uk for 92x92 grid points operational UK mesoscale model,
- *type* indicates if the data have any time dependence, thus:
  - parm for constant fields, eg. orography,
  - clim for climatologies, eg. sea surface temperature,
  - m if valid for one particular month,
- *data* indicates the file contents, eg. mask, orog, sst, veg, soil
- *suffix* is optional

N.B: for climate users - 'clim' files in the cl_9673 directory have headers set for the standard climate 360 day year, whereas files in the cl365_9673 directory have headers set for the Gregorian 365 day year. All other domains only have files for the 365 day year.

3.6.3 Generation of new ancillary files

Atmosphere ancillary files for a new domain can be created using a master program which has gathered together all available code. (Such a program does not yet exist for ocean ancillaries, but is being developed.) A script to run this program and generate one or more ancillary files can be obtained by making a copy of the IBM dataset MS15.DRANCILL.VNnm(@ANCILSC), where nm is a version no., eg. 34 for version 3.4, 40 for version 4.0. Then follow the instructions contained therein. The script is run on the Cray C90 and among its output includes simple maps of land/sea mask and orography for you to inspect. N.B: Make a note of the 'No of Land Points' as this value is required by the UMUI when setting up a forecast run.

Before using these files, you would be well advised to make a careful scrutiny of the land/sea mask, which influences all the other ancillary files except ozone, to make sure it meets your requirements. Be aware that, while single grid point islands or sea inlets will not cause model failures, they could give rise to unsightly or unrealistic effects in surface and boundary layer fields.

If you set NEWGRID=true, be careful not to introduce any spaces when setting ROW_LENGTH=123 etc. as these are Unix environment variables, not Fortran namelist assigns. Make sure you enter values to exactly the same precision as you will use in the UMUI when setting up experiments, else your runs may fail internal consistency checks, and make sure longitudes are in the range **0 - 360** degrees as this is what the UMUI requires.

3.6.4 UMUI aspects

The information in this section will make more sense if you read it in conjunction with an active UMUI session - if necessary copy a standard experiment (see section 3.2) for the purpose. Window titles given are those under the section

`Atmosphere`

Similar ones exist for the Ocean Model in the section

`Ocean GCM`

The section
```
Atmosphere
-> Ancillary and input data files
```
is where your ancillary files (if any) are specified. There is a window for each possible ancillary file, most of which contain several fields. These windows control how each field is to be used, both in the reconfiguration step and during the model run. The reconfiguration program is only executed if reconfiguration is selected in window **atmos_InFiles_Start**
```
Atmosphere
-> Ancillary and input data files
--> Start Dump
---> Start Dump
```

The section
```
Atmosphere
-> Ancillary and input data files
--> Climatologies & potential climatologies
```
covers most ancillary files, but the section
```
Atmosphere
-> Ancillary and input data files
--> Other ancillary files and Lateral Boundary files
```
contains orography and land/sea mask files.

Each window has a similar pattern:

- Specify ancillary file as directory and filename. Directory may be a full pathname or an environment variable specified in the window **subindep_FileDir**
  ```
  Sub-Model independent
  -> File and Directory Naming
  ```
- For each field in the file specify whether or not it is to be:
  - Configured, i.e. read in from the ancillary file in the reconfiguration step. If not, values from the initial dump will be used. Note that these will be interpolated if the initial dump is for a different domain and resolution from the model, but only if reconfiguration is selected in window **atmos_InFiles_Start**.
  - Updated, i.e. set to values time interpolated from the ancillary file at a specified interval. If not, values may be computed by the model as it runs (eg. snowdepth) or may be fixed (eg. ozone) - this depends on what is possible for each field - see the particular UMUI panel for details.
  - Not used. In fact this means that, if the field is required by the model, it will be taken from the original dump.
- For some fields, notably orography and land/sea mask, updating is not a valid operation, so the only choice is to configure or not.

Warnings

Before asking for ancillary files to be used, stop and ask if it is necessary and what the implications are.

If the model run you are setting up is on the same domain and resolution as your initial dump, then many or all of the ancillary fields may already be there. If they are not and you wish to read in data from an external file, then ensure the file was made for your domain and resolution. Be aware that, up to and including version 3.3, if reconfiguration of orography and/or land/sea mask was requested, then interpolation routines were be called

for the prognostic variables, thus negating bit-comparability, even if domain and resolution are not changed. From version 3.4 onwards, checks are included in the reconfiguration to suppress horizontal interpolation if land/sea mask is identical to that in the dump, and to suppress vertical interpolation if orography (and model levels) is identical.

If you wish to run with a domain and/or resolution different from your initial dump, ancillary fields in your dump (and prognostic variables too) will be interpolated. Is the resultant loss of detail acceptable to you? If not, then you must create and configure from ancillary files on your domain and resolution.

Window: **atmos_InFiles_Options_Headers**
`Atmosphere`
`-> Ancillary and input data files`
`--> In file related options`
`---> Header record sizes`
allows you to "specify the total number of lookup headers on the ancillary files used for updating" for atmosphere (and similarly for ocean). This is typically set to 300 in the standard experiments, which is usually plenty, but if you are using a multi-level, multi-time ancillary file (eg. an aerosol climatology) you may need to increase this value.

Window: **subindep_AncilRef**
`Atmosphere`
`-> Ancillary and input data files`
`--> In file related options`
`---> Ancillary reference time`
OR
`Sub-Model Independent`
`-> Ancillary reference time`
allows you to specify a reference time from which all ancillary field updating times will be computed. Setting all zeroes allows the dump basis time to be used, but climate users will often want to specify a convenient reference time. Specifying a fixed ancillary reference time ensure bit comparison when starting a new run from a dump made part way through a previous run.

3.6.5 Model aspects

This is difficult to document simply, but fortunately a new user does not normally need to know the details.

The interpolation, replacement or addition of ancillary fields by the stand-alone reconfiguration program is covered separately (see section 3.7).

Within the model itself, control of ancillary fields is supposedly by the namelist &ANCILCTA (and &ANCILCTO) in the umui_jobs directory files CNTLATM (and CNTLOCN). However, the only things it really controls is whether to update a specific field and, if so, at what frequency.

Whether the data are single-time or multi-time, and whether updating is regular/irregular, periodic/non-periodic or time-series, are controlled by the ancillary file header. See UMDP F3 [23] for details.

Whether the calendar is Gregorian or 360 day is controlled by the logical LCAL360 set in window **subindep_Control**
`Sub-Model Independent`
`-> General Configuration and Control`
(Climate users be careful to use ancillary files created for the right year-length.)

All other controls, such as:

- inter-field dependencies, eg. SST and sea-ice,

- time interpolation using simple linear interpolation, but controlled linear interpolation for snow depth and SST & sea-ice fields,
- whether to update land points, sea points or all points,

are coded within the subroutine REPLANCA (and REPLANCO). For full details see UMDP C7 [21].

3.6.6 Boundary updating files

Being an external file which updates model prognostic values during a model run, albeit only at a small number of lateral boundary points, a boundary data file can rightly be termed an ancillary file.

It is specified in the UMUI window **atmos_InFiles_OtherAncil_LBC**

```
Atmosphere
-> Ancillary and input data files
--> Other ancillary files and Lateral Boundary files
---> Lateral boundary conditions
```

in the same section as orography and land/sea mask.

However, they are generated, not by the central ancillary program, but in a run of a UM experiment covering a larger domain, specifications being set in panels under

```
Atmosphere
-> Control
--> Output data files (LBCs etc)
---> LBC's out
```

For a detailed description of the structure and the contents of a boundary update file see UMDP C7 [21], Appendix 2.

3.6.7 User Ancillaries

Introduction

The UM allows users to add new prognostic fields (ie. fields that define the atmospheric state and are required to perform the integration) and new ancillary fields (ie. fields that act as boundary conditions to the integration) - 'User prognostics' and 'User Ancillaries' respectively. User prognostics may be set up using any item number and can be initialised in the reconfiguration. Setting up user ancillaries is more restrictive and the user must choose from a list of reserved item numbers for single and multi-level ancillary fields.

The UM code has been set up to add user ancillaries through four ancillary files recognised in the UM system by their names as follows:

- USRANCIL : Atmosphere - Single level user ancillaries
- USRMULTI : Atmosphere - Multi-level user ancillaries
- OUSRANCL : Ocean - Single level user ancillaries
- OUSRMULT : Ocean - Multi-level user ancillaries

This set up simplifies the process of adding ancillary fields which normally requires extensive changes to the UM code. Ancillary fields provided through these four files will be recognised and read in; the user then has to provide code changes to use these fields within the model.

How to set up User Ancillaries

The user will need to take the following steps:

- Create a User Stashmaster file (USMF).

  Stashcodes (in section 0) have been reserved for the user ancillaries as follows:

  - USRANCIL : 20 fields, Stashcodes 301-320
  - USRMULTI : 4 fields, Stashcodes 321-324
  - OUSRANCL : 10 fields, Stashcodes 331-340
  - OUSRMULT : 4 fields, Stashcodes 351-354

  Detailed information on setting up a USMF can be found in UMDP C4 [19] (page 13).

- Attach the USMF to the UMUI in windows **atmos_STASH_UserDiags** or **ocean_STASH_UserDiags**
  `Atmosphere` OR `Ocean`
  `-> Stash`
  `--> Specification of User Diagnostics`
  Several USMFs may be attached. They must be set up before entering STASH and be on the same platform as the UMUI client.

- Set up to initialise the User Ancillaries from data in the ancillary files. This is done in window **atmos_STASH_UserProgs** or **ocean_STASH_UserProgs**
  `Atmosphere` OR `Ocean`
  `-> Stash`
  `--> Initialisation of User Prognostics`
  The user needs to consider whether or not the ancillary field is being updated in the model run.

  - If the ancillary field is NOT to be updated, select option 7 and attach the user ancillary file in the right hand column. The field will be initialised in the reconfiguration step.
  - If the ancillary field IS to be updated, select option 2. The field will be initialised with the ancillary data at timestep 0.

- For ancillary fields to be updated,

  - specify the location(s) of the ancillary files
  - specify an update frequency.

  through the following windows:

  - For atmosphere user ancillaries: windows **atmos_InFiles_PAncil_UserM** and/or **atmos_InFiles_PAncil_UserS**
    `Atmosphere`
    `-> Ancillary and input data files`
    `--> Climatologies & potential climatologies`
    `---> User multi-level ancillary file and fields`
    and/or
    `---> User single-level ancillary file and fields`

- For ocean user ancillaries: windows **ocean_InFiles_PAncil_UserM** and/or **ocean_InFiles_PAncil_UserS**

```
Ocean GCM
-> Input Files
--> Climatologies \& potential climatologies
---> User multi-level ancillary file and fields
```

and/or

```
---> User single-level ancillary file and fields
```

WARNINGS on setting up user ancillaries

- Note that the UMUI allows one update frequency per ancillary **file** and not **field**. The same updating frequency applies to any fields being updated in the ancillary file. However, if necessary, the updating frequency could be over-written (by experienced users) by hand-editing the 'FIELDCODE' values in the ANCILCTA/O namelists in the CNTLATM/CNTLOCN files for your processed job.
- Code changes will be required to the REPLANCA subroutine depending on whether the field is on all points, land points or sea points. It is assumed that
  - the atmosphere single level ancillaries will be for land points only.
  - the atmosphere multi-level ancillaries will be for all points and the full set of model levels (P_LEVELS).

3.7 Reconfiguration

Author: D.M. Goddard, Last Updated: 29 Mar 96

3.7.1 Introduction

The reconfiguration is a standalone program which allows the user to modify dump files. A dump file contains the necessary data to define the initial conditions for a model run in the format described in UMDP F3 (see [23]). The reconfiguration program will process both atmospheric and oceanic data, however its functionality for ocean dumps is limited.

The following facilities are available for atmospheric and oceanic data:

- Upgrading a dump from earlier releases of the model. Backward compatibility is generally not supported, but may work in some circumstances.
- Adding fields to or subtracting fields from the dump.
- Adding user defined fields to the dump.
- Adding tracers to the dump

The following facilities are also available only for the atmospheric data

- Interpolating to a new resolution or domain.
- Initializing fields with ancillary data.
- Incorporating UARS upper air analyses into the dump.
- The incorporation of ensemble perturbation: whereby ECMWF analysis increments are used to adjust prognostic fields in the dump file.
- A transplant option: A facility to replace prognostic data over part of the domain with prognostic data from another dump.

Note that any data from sources external to the model *eg ancillary files* must be at the same resolution and on the same domain as the output dump.

The reconfiguration is run as part of a UM job submitted from the user interface. The initial conditions are input through the user interface and processed into a series of namelists in the RECONA (RECONO for ocean) file in the UM job directory. The reconfiguration may be switched on or off through the user interface.

3.7.2 When does a dump file need reconfiguring?

A file needs reconfiguring if:

1. There is a change of resolution or area. The dump needs to be interpolated onto the new domain.
2. There is a request for configuration from an ancillary file. The ancillary data may overwrite existing data or may form a new field.

3. The dump needs to be upgraded to a new model release involving a change in dump format. Then the reconfiguration is needed to convert the dump to the new format. See UMDP F3 [23] for changes in format. *Note the reverse procedure may not work.*

4. New user prognostics, ensemble perturbation, tracers or transplanted prognostic data are requested. Then the reconfiguration reserves space in the dump for these fields and initializes them. See UMDP S1 [28] for details.

3.7.3 Defining a reconfiguration using the UMUI

Define for all configurations

- Select window **subindep_Control**
  `Sub-Model Independent`
  `-> General Configuration and Control`
  The user can specify a reconfiguration only run by clicking on the box next to the statement "perform the reconfiguration step only".

- Select window **subindep_FileDir**
  `Sub-Model Independent`
  `-> File and Directory Naming`
  The user may define here environmental variables for directories which are to be used later to point to file names. *eg in the next section the executable can be written to directory $EXEC where EXEC was defined in this section as mydir/exec.*

- Select window **subindep_CompRecon**
  `Submodel Independent`
  `-> Modifications for the reconfiguration`
  The user may select to use the standard reconfiguration executable, use another executable or build a new executable. If a new executable is to be built, the user must specify the file name and directory to which the new executable is to be written and any modsets and compiler options to be used in the build.

- The windows referenced in the following are for the atmosphere submodel but similar windows can be found for the ocean and slab submodels by following the ocean or slab branches instead of the atmosphere branch.

  - The contents of the dump file depends on which scientific sections are requested. *For example* **Soil moisture in layer (STASH code 9)** *will only be incorporated into the dump if* **multi-layer hydrology** *sections are used.* So the user must specify what sections are required for the model run even if the model is run in reconfiguration only mode. In such circumstances the user should look at how the reconfigured dump is to be used. This will determine what needs to be in the reconfigured dump.
    To view and change the scientific sections selections look in the UMUI section
    `Atmosphere`
    `-> Scientific Parameters and Sections`
    `--> Section by section choices`
  - Select window **atmos_STASH_UserDiags**
    `Atmosphere`
    `-> STASH`
    `--> Specification of user diagnostics`
    In this panel the user should specify any user preSTASHmaster containing user prognostics which are to be included in the dump. *Note that this file must be local to the machine from which the UMUI is being run.*

- Select window **atmos_STASH_UserProgs**
  Atmosphere
  -> STASH
  --> Initialization of User Prognostics
  In this panel the user selects the method of initialization of the user prognostics added to the dump in the previous panel.

Define for atmosphere submodel

- Select window **atmos_Domain_Horiz**
  Atmosphere
  -> Model Resolution and Domain
  --> Horizontal
  In this window the user defines atmospheric model horizontal resolution, domain and number of land points.

- Select window **atmos_Domain_Vert**
  Atmosphere
  -> Model Resolution and Domain
  --> Vertical
  In this window the user defines atmospheric model levels.

- Select window **atmos_Config_Prognos**
  Atmosphere
  -> Model configuration
  --> Prognostic variable choice
  In this window the user may add SST anomalies and aerosol fields to the dump.

- Select window **atmos_Config_Tracer**
  Atmosphere
  -> Model configuration
  --> Tracers
  In this window the user may add atmospheric tracers to the dump.

- Select window **atmos_Infiles_Start**
  Atmosphere
  -> Ancillary and input data files
  --> Start dump
  In this window the user specifies whether or not to reconfigure the dump. If so the user is then asked to specify the name of the initial dump, the name of the reconfigured dump, the type of horizontal interpolation and the type of coastal adjustment. Horizontal interpolation and coastal adjustment are discussed in section 3.7.5. If reconfiguration is not required, the user need only specify the initial dump. If the initial dump is in GRIB format, the user must reconfigure the dump and switch on the ECMWF GRIB switch.

- The user should then select which fields are required from ancillary files.

  - Some of these are climatological datasets and are accessed from the section
    Atmosphere
    -> Ancillary and input data files
    --> Climatologies and Potential climatologies

- The remainder including *Land-sea mask* and *Orography* can be accessed from the section
  `Atmosphere`
  `-> Ancillary and input data files`
  `--> Other ancillary files and Lateral Boundary files`

See section 3.6 for more information about ancillary files and section 3.6.4 for more details on how to fill in the panels.

Define for ocean submodel

- Select window **ocean_Domain_Horiz**
  `Ocean GCM`
  `-> Model Resolution and Domain`
  `--> Horizontal`
  In this window the user defines ocean model horizontal resolution and domain *Note this must be the same as the input dump, as interpolation is not available for Ocean dumps.*

- Select window **ocean_Domain_Vert**
  `Ocean GCM`
  `-> Model Resolution and Domain`
  `--> Vertical`
  In this window the user defines ocean model vertical resolution and domain. *Note this must be the same as the input dump, as interpolation is not available for Ocean dumps.*

- Select window **ocean_Tracer_UserDef**
  `Ocean GCM`
  `-> Tracers`
  `--> User Defined Tracers`
  In this window the user may add oceanic tracers to the dump.

- Select window **ocean_Infiles_Start**
  `Ocean GCM`
  `-> Input files`
  `--> Start dump`
  In this window the user specifies whether or not to reconfigure the dump. If so the user is then asked to specify the name of the initial dump and the name of the reconfigured dump. If reconfiguration is not required, the user need only specify the initial dump.

- The user should then select which fields require initialisation from other input files.

  - Some of these are climatological datasets and are accessed from the section
    `Ocean GCM`
    `-> Input files`
    `--> Climatologies and Potential climatologies`
  - If extra tracers were requested these may need to be initialized from ancillary data. Select **ocean_Infiles_OtherAncil_Tracer**
    `Ocean GCM`
    `-> Input files`
    `--> Other ancillary/input files`

See section 3.6 for more information about ancillary files and section 3.6.4 for more details on how to fill in the panels.

Define for slab submodel

- The user should select what fields are required from ancillary files. This is done in a series of windows in the section
  `Slab Ocean`
  `-> Ancillary files`

See section 3.6 for more information about ancillary files and section 3.6.4 for more details on how to fill in the panels.

3.7.4 Changing the resolution of the dump

The minimum requirement when reconfiguring to a new resolution is to state the number of land points in the interpolated land-sea mask at the new resolution. Then all the fields will be automatically interpolated to the new resolution from the original dump by the reconfiguration program.

For a more realistic representation where more accurate simulations are needed, it is better to use dedicated ancillary files at the new resolution which have been derived from high resolution base data.

Warning: *Care must be taken with special fields such as orography and the land-sea mask. Requesting either of these from an ancillary file will cause interpolation, Interpolation can negate bit comparison as it affects other fields.*

3.7.5 Interpolation

Interpolation is the mechanism by which data is transformed from one resolution to another. The reconfiguration offers a choice of a bilinear technique or an area weighted technique to interpolate horizontally and assumes a linear relationship with log pressure to interpolate vertically. See UMDP S1 [28] for more details.

For general use the bilinear technique is recommended, however if interpolating onto a coarser grid the area weighted technique is preferred.

The reconfiguration also has a coastal adjustment step, which adjusts land specific fields at coastal points where horizontal interpolation uses a mixture of land and sea points. The spiral coastal adjustment scheme is recommended here as the other scheme may generate inappropriate results when the nearest land points are far removed geographically from the coastal points. This is also explained in UMDP S1.

3.8 Changing Resolution

Author: Richard T.H. Barnes / Terry Davies, Last Updated: 12 Apr 96

3.8.1 Introduction

The Unified Model is designed to run at any horizontal resolution reasonable for a hydrostatic model, from coarse climate resolution with just 10's of grid-points in each direction to high resolution limited area models with grid-lengths down to 5km (0.05 degrees), provided sensible parameters are chosen. Section 3.8.2 covers the basic windows involved in changing horizontal resolution.

Changing vertical resolution, however, needs to be done with great care. In particular, avoid too great a difference between the thicknesses of nearby levels and make sure there is no oscillation of thicknesses of adjacent levels. That is, the half-level eta values that specify the vertical coordinate should be smoothly varying. The 2 sets of vertical levels in the standard jobs (19 for global and LAM, 31 for mesoscale) are well tested. Section 3.8.4 lists the windows involved if you do have to change vertical resolution.

3.8.2 Windows to Change Horizontal Resolution

1. Window: **atmos_Domain_Horiz**
   `Atmosphere`
   `-> Model Resolution and Domain`
   `--> Horizontal`
   As well as the Numbers of Columns and Rows, you will need to change the Number of Land Points - you may need to run your job once with a wrong value and let it fail to determine this value. If you are reconfiguring, search for 'No of land points =' in the output, near the land sea masks. The model's failure message near the end of the output will be 'SETCONA: Wrong number of land points', with just above it 'I=' also giving the correct number of land points and 'LAND_FIELD=' giving the value that is wrongly set.

2. Window: **atmos_Science_Tstep**
   `Atmosphere`
   `-> Scientific Parameters and Sections`
   `--> Time-Stepping`
   An increase in resolution normally needs to be accompanied by a reduction in timestep. If the 'period' is kept as 1 day, this means increasing the Number of timestep per 'period'.

3. Window: **atmos_Science_Onlevel**
   `Atmosphere`
   `-> Scientific Parameters and Sections`
   `--> Level-by-level Constants, Physical Constants`
   If model resolution has been significantly changed, the run is likely to fail within a few timesteps if the diffusion coefficients have not been scaled to be suitable for the new grid-length and timestep. See section 3.8.3 on changing horizontal diffusion for the issues involved here.

4. Window: **atmos_Science_Section_DiffFilt**
   `Atmosphere`
   `-> Scientific Parameters and Sections`
   `--> Section by section choices`
   `---> Diffusion and Filtering`
   Depending on the height of the highest orography in your domain, you may be able to increase the

pressure altitude (i.e. lower the model level) up to which horizontal diffusion is switched off over steep slopes. See section 3.8.3 for details.

5. Windows: **atmos_Science_Section_SW, atmos_Science_Section_LW** and **atmos_Science_Section_Conv**
   `Atmosphere`
   `-> Scientific Parameters and Sections`
   `--> Section by section choices`
   `---> SW Radiation` OR `LW Radiation` OR `Convection`
   Increasing resolution will increase the memory requirements of the model - you may want to increase the "Number of segments" particularly for Long-wave and Short-wave Radiation, and possibly for Convection, to alleviate this.

6. Window: **subindep_JobRes**
   `Sub-Model Independent`
   `-> Job resources and re-submission pattern`
   Choose suitable new values for the job resources, particularly memory and time. As a rough guide, scale the memory limit in proportion to the change in number of grid points (though increasing the 'segments' for the large physics sections may alleviate this). Scale the time limit in proportion to the change in number of grid points and number of timesteps required to complete the forecast (though the cost of compilation will remain fairly constant). Check the actual amounts used and refine your choices if necessary.

7. Windows in the section:
   `Atmosphere`
   `-> Ancillary and input data files`
   The portable model package only supplies global dumps and ancillary files for climate resolution (96x73 grid-points on 19 vertical levels). The reconfiguration program will interpolate dumps to other resolutions. However, the ancillary files cannot be used in model runs at other resolutions, so for these you must ensure that windows relating to ancillary files have "Not used" set for all ancillary fields. The model will fail with suitable error messages if you try to "Update" ancillary fields from climatological ancillary files at the wrong resolution. The reconfiguration program will fail if you try to "Configure" from ancillary files at the wrong resolution.

3.8.3 Changing Horizontal Diffusion

The formula for horizontal diffusion is given by equations 47 and 48 of UMDP 10 [5]. Essentially this is a conservative form of a Laplacian-type operator and repeated application gives higher-order diffusion. Higher-order diffusion is considered beneficial because it is more scale selective i.e. there is more damping on the less-accurate shorter scales than on the meteorologically important longer scales. However, the higher the order of diffusion the more expensive it is to use. In the integration scheme used by the UM, extra damping is required for high-resolution limited-area modelling as a means of controlling grid-splitting in extreme cases.

The diffusion coefficient used depends upon resolution and timestep and has to be chosen carefully to avoid having either too little or too much damping overall. The behaviour of the diffusion operator can be analysed by considering its behaviour on a wave-like structure. In practice, a one-dimensional analysis is adequate to estimate the diffusion coefficient. Once chosen, the final value can be refined by trial and error.

The effect of applying the diffusion to a 2 grid-length wave is given by:

$$D = 1 - \frac{2^{2k} K^k \Delta t}{\Delta x^{2k}}$$

where K is the diffusion coefficient, k is the order of diffusion, Δt is the timestep in seconds and Δx is the grid-length in metres. We choose the diffusion coefficient K as the value which reduces the amplitude of the

2 grid-length wave by $1/e$ after N applications of the horizontal diffusion. Thus, we require $D = e^{-1/N}$. Therefore the expression for the diffusion coefficient K is

$$K = \frac{1}{4}\Delta x^2 \left(\frac{1 - e^{-1/N}}{\Delta t} \right)^{1/k}$$

This expression can be evaluated on a calculator or a simple program may be written to output various values of K given the input values which are repeated here

- Δx = the approximate horizontal grid-length in metres
- Δt = the dynamics timestep in seconds
- N = the number of dynamics steps over which the 2 grid-length wave amplitude reduces by $1/e$ (the damping time is then $N * \Delta t$, e.g. say 6 hours is required for the climate model using a 30 minute dynamics timestep, then N = 6 hours / 30 minutes = 12). As can be seen in the examples below, the higher the resolution (smaller grid-length) then the shorter the damping time.
- k = the order of diffusion (k = 1 for ∇^2, 2 for ∇^4, 3 for ∇^6, etc).

The value of K returned need not be used exactly since the above formula is only a guide in one-dimension. Usually just one or two significant figures are sufficiently accurate. When used in the dynamics, the diffusion coefficient in the east-west (longitudinal) direction is scaled with the latitude so that the diffusion operates on the same length scales everywhere regardless of the convergence of the meridians. Below are some examples produced by the formula (using Fortran on an HP workstation), followed by the values actually used in the models.

- Climate Model: Δx = 280km, Δt = 1800 seconds, N = 24 (12 hour damping) K = 5.54742E+08 for third order (∇^6) diffusion. K = 5.47E+08 is used in climate versions.
- Global Model: Δx = 100km, Δt = 600 seconds, N = 6 (1 hour damping) K = 3.99894E+07 for second order (∇^4) diffusion. Use K = 4.0E+07 as used operationally.
- LAM: Δx = 50km, Δt = 300 seconds, N = 4 (20 minutes damping) K = 1.69711E+07 for second order (∇^4) diffusion. Use K = 1.7E+07 as used operationally.
- Mesoscale: Δx = 17km, Δt = 100 seconds, N = 5 (500 seconds damping) K = 3.076096E+06 for second order (∇^4) diffusion. Use K = 3.0E+06 as used operationally.

Note that at the top level, extra diffusion is normally applied since extra damping is required at least for winds and thetal. The suggested values are:

- Climate Model: Δx = 280km, Δt = 1800 seconds, N = 2.5 (1.25 hour damping) K = 3.59E+06 for first order (∇^2) diffusion. Use K = 4.0E+06.
- Global Model: Δx = 100km, Δt = 600 seconds, N = 3 (1/2 hour damping) K = 1.181119E+06 for first order (∇^2) diffusion. Use K = 1.0E+06 as used operationally.
- LAM: Δx = 50km, Δt = 300 seconds, N = 4 (20 minutes damping) K = 4.608316E+05 for first order (∇^2) diffusion. Use K = 4.25E+05 as used operationally.
- Operational Mesoscale Model: uses the same values at all levels.

The other diffusion parameter over which the user has control is the level at which the horizontal diffusion is switched off over steeply sloping model coordinate surfaces. This is specified in the window:
atmos_Science_Section_DiffFilt

```
Atmosphere
-> Scientific Parameters and Sections
--> Section by section choices
---> Diffusion and Filtering
```

Typically, these surfaces are near the ground over mountains but the highest mountains in the UM make the model coordinate surfaces slope significantly even above 300hPa over the Himalayas and the Andes. Since this modification to the diffusion adds to the running cost of the model there is no need to apply the slope test where the model surfaces are horizontal, which is at least true for the levels that are pure pressure levels. The *pressure_altitude* used in global configurations is best set to 20000Pa (200hPa) if we wish to test for all sloping coordinate surfaces. Limited-area configurations can be changed according to the typical pressure just above the top of the highest orography in the region e.g. the UK Mesoscale model could use 70000Pa (700hPa). A large pressure value e.g. 200000Pa (2000hPa) can be used to switch off the slope test in the diffusion but this leads to noisy and sometimes unrealistic rainfall over mountains and in the Mesoscale model reduces the accuracy of fog forecasts.

3.8.4 Windows to Change Vertical Resolution

1. Window: **atmos_Domain_Vert**

   ```
   Atmosphere
   -> Model Resolution and Domain
   --> Vertical
   ```

   "Pressure weighted mean" is the recommended way of calculating model levels. As well as choosing Number of levels and 'wet' levels (those at which moisture calculations are included), you have to specify the 'half-levels' up to which the vertical coordinate is purely 'sigma' and at and above which it is purely pressure. In between these a 'hybrid' vertical coordinate is used.

   Given these constraints, the positioning of levels is specified by a set of values of 'eta' for the n+1 half-levels, decreasing monotonically from 1.0 for the Earth's surface to a small number (typically 0.0005) for the 'top' of the atmosphere. These values should be smoothly varying as the sudden introduction of very thin or thick levels (or oscillations in level thicknesses) can cause unrealistic model behaviour, particularly in the physics routines. It is also best to leave the top 4 half-levels as set in the standard jobs, since model stability at the upper boundary has been found to be sensitive to these values.

   Number of boundary layer levels is normally the number with eta values up to about 0.8, approximately equivalent to 800hPa. Leave number of deep soil levels unchanged here. Set number of cloud levels used in radiation to minimum of number of wet levels and number of levels-1. The other level parameters for gravity wave drag and vertical diffusion are best set by reference to the "Help" given in their respective windows in the section

   ```
   Atmosphere
   -> Scientific Parameters and Sections
   --> Section by section choices
   ```

2. Window: **atmos_Science_Onlevel**

   ```
   Atmosphere
   -> Scientific Parameters and Sections
   --> Level-by-level Constants, Physical Constants
   ```

   If you have added levels, the values in these tables will need extended. The mesoscale model uses a different set of low level critical humidity ratio values from the other standard configurations.

3. Windows: **atmos_Science_Section_SW, atmos_Science_Section_LW** and **atmos_Science_Section_Conv**
   `Atmosphere`
   `-> Scientific Parameters and Sections`
   `--> Section by section choices`
   `---> SW Radiation` OR `LW Radiation` OR `Convection`
   Increasing vertical resolution will also increase the memory requirements of the model - you may want to increase the "Number of segments" particularly for Long-wave and Short-wave Radiation, and possibly for Convection, to alleviate this.

4. Window: **subindep_JobRes**
   `Sub-Model Independent`
   `=> Job resources and re-submission pattern`
   Choose suitable new values for the job resources, particularly memory and time. As a rough guide, scale the memory limit in proportion to the change in number of grid points (though increasing the 'segments' for the large physics sections may alleviate this). Just changing the vertical resolution does not necessarily require changing the timestep, so also scale the time limit in proportion to the change in number of grid points - though the cost of compilation will remain fairly constant). Check the actual amounts used and refine your choices if necessary.

5. Windows in the section:
   `Atmosphere`
   `-> Ancillary and input data files`
   The portable model package only supplies global dumps and ancillary files for climate resolution (96x73 grid-points by 19 levels). The reconfiguration program will interpolate dumps to other resolutions, both horizontally and vertically. However, the ancillary files cannot be used in model runs at other resolutions, so for these you must ensure that windows relating to ancillary files have "Not used" set for all ancillary fields - the model will fail with suitable error messages if you try to "Update", and the reconfiguration program will fail if you try to "Configure", with ancillary files at the wrong resolution. With changes to number and disposition of model levels this applies particularly to the ozone ancillary file. See section 3.6.3 for notes on creating new ancillary files for new grids.

3.9 Selecting a New LAM Area

Author: Richard T.H. Barnes, Last Updated: 12 Apr 96

3.9.1 Preliminaries

Setting up the Unified Model for a new domain is relatively straightforward, and will enable you to run higher resolution experiments concentrating on your area of interest. However you should at the outset consider the time and effort involved.

The time will be 2 days to a week or so of dedicated work, to get a smoothly running Limited Area Model on a new domain, depending on experience. Because of the work involved in preparing acobs files, running an experiment with data assimilation on a new domain requires further work. If this is required, consult the section on 3.5.

Your initial thoughts about what you want from your experiment should include:

- size of domain, horizontal resolution, number and spacing of levels
- choice of physics versions
- order and coefficients of diffusion (if you change grid length)
- initial data, boundary conditions, and length of forecast
- ancillary files (if any)
- STASH diagnostic output
- job resources

3.9.2 Overview

The work required can be split into 4 areas, some of which can be carried out in parallel. They will be described in detail below:

1. Choose new LAM domain
2. Create new ancillary files
3. Set up and run UM to generate boundary data
4. Set up and run UM to produce new LAM forecast

Tasks 2 and 3 can be done in parallel, along with the "set up" stage of task 4.

3.9.3 Choose new LAM domain

This can be done by spherical trigonometry or trial and error, but the most convenient way for MetOffice users is the "lampos" graphical utility on the NWP HP-system.

The following 8 data will be needed for subsequent steps (write them down or use the print facility):

- latitude and longitude of rotated pole
- x and y direction gridlengths (lampos assumes these will be equal)
- x and y grid dimensions in gridlengths
- latitude and longitude of "top left corner" of domain (relative to rotated pole)

Conceptually it is simplest to think of situations where the equator/meridian crossing of the rotated grid, "+" on the lampos display, is roughly in the centre of the domain, as with the operational LAM and UK mesoscale model. However it is not essential for the rotated equator/meridian point to be within the domain, and further rotation of the domain can be achieved by moving the rotated meridian outside of the domain and adjusting the coordinates of the top left corner accordingly. Navigating the rotated pole to the best location can be quite tricky, and exploring the possibilities with "lampos" is a great help.

In particular, to get into the Southern Hemisphere requires specifying an "imaginary" latitude, greater than 90N, for the rotated pole. The Unified Model system (ancillary file creation and forecast model) will accept and run with such an imaginary latitude, but it has been found that some pp-package based utilities will not then display the correct map background, so beware.

An alternative approach, which gives an identical forecast and a correct map background, is to "mirror" back to a rotated latitude between 0 and 90N by subtracting from 180, eg. 110N => 70N. Then swing the rotated longitude through 180 degrees, and also add 180 degrees to the longitude of the top left corner.

When selecting your new domain, it will save time on tuning the model to choose a tried and tested resolution for which diffusion coefficients etc. are known. For guidance "lampos" also gives approximate figures for the resources required to run a model of your chosen dimensions and duration.

3.9.4 Create new ancillary files

This step is not essential as you could simply reconfigure (see section 3.7) from a global dump to get initial conditions for your run. However, the resulting land/sea mask, orography and other fields so interpolated will be smooth and lacking in detail. For your new domain, you will almost certainly want to create new land/sea mask and orography files at your chosen resolution. Most people also make new soil and vegetation ancillary files for their new LAM domain.

To do this make a copy of the IBM dataset MS15.DRANCILL.VNnm(@ANCILSC), where nm is a version no., eg. 34 for version 3.4, 40 for version 4.0, and follow the instructions contained therein. The script is run on the Cray C90 and its output includes simple maps of land/sea mask and orography for you to inspect. N.B. Make a note of the 'No of Land Points' as this value is required by the UMUI in task 4.

If you set NEWGRID=true, be careful not to introduce any spaces when setting ROW_LENGTH=123 etc. as these are Unix environment variables, not Fortran namelist assigns. Make sure you enter values to exactly the same precision as you will use in the UMUI for tasks 3 and 4, else your runs may fail internal consistency checks, and make sure longitudes are in the range **0 - 360 degrees** as this is what the UMUI requires (even though lampos allows negative longitudes).

3.9.5 Set up and run UM to generate boundary data

This step is not essential as the Unified Model can run as a limited area model with fixed boundary conditions, but, except for idealised experiments, beyond a few hours the forecast will become unrealistic without realistic boundary data.

Typically you will run a global model to provide boundary conditions for a limited area model (LAM). However, it is possible to drive higher resolution LAMs from another LAM. Eg. the UK Mesoscale model is driven by boundary data generated by the operational LAM.

To copy an existing or standard (see section 3.2) global experiment, use mouse clicks to highlight the job to copy and an experiment to receive it. Use the "Job" & "Copy" commands at the top of the GHUI entry window of the UMUI system. Enter a suitable description and select an unused identifier. When the copy has completed, unhighlight those 2 lines and highlight the new one. Use "File" & "Open read/write" to open your new experiment. All the windows you must enter are listed below:

Window: **subindep_Runlen**
```
Sub-Model Independent
-> Start Date and Run Length Options
```
Set start time for this run and length of forecast to generate enough boundary data for your LAM run.

Window: **subindep_Section_Misc**
```
Sub-Model Independent
-> Sub-Model Independent Section Choices
--> Miscellaneous Sections
```
Make sure that section 19 for Lateral boundary tendencies has "1A, standard version" chosen.

Window: **atmos_Control_OutputData_LBC1**
```
Atmosphere
-> Control
--> Output data files (LBCs etc)
---> LBCs out
```
Click on Stream 1 (or the next available stream if you wish to preserve what is in already active streams) and click on "next" to open the data entry window **atmos_Control_OutputData_LBC2**. Set:

- whether data are to be packed (usual on Cray C90) or not (probably necessary on other platforms).
- frequency, start and end times for boundary data generation.
- the 8 data specifying the domain (see section 3.9.3).
- rimwidth in gridlengths of the boundary data (usually 4) - this gives more realistic fields near the boundaries than when boundary data are applied only at the edgemost points.
- you will not want files re-initialised except for long climate LAM runs.

Press "next" for a further window, and specify whether the vertical grid for the LBCs is to be different from the driving model - if it is, seek guidance in specifying a suitable set of "eta half levels". Only 19 levels (as in global & LAM) and 31 levels (as in mesoscale) have been extensively tested. See also section 3.8.4 on vertical resolution.

Boundary data will be generated on a file named *runid*.alabcou*n*, where *runid* is the 5 character code of your experiment id and job id, and *n* is the output stream selected.

If you want to start your LAM run at other than T+0 of this run, you may want a dump from this run at, say, T+6. Go to window **atmos_Control_PostProc_DumpMean**

```
Atmosphere
-> Control
--> Post-processing, Dumping & Meaning
--=> Dumping & Meaning
```

to request this, and click on "next" to open the data entry window **atmos_Control_PostProc_DumpMean2** for irregular dump times.

The rest of this job is no different from a normal global run.

Make sure you "Save" and "Process" before you "Submit" the job.

3.9.6 Set up and run UM to produce new LAM forecast

To copy an existing or standard (see section 3.2) LAM or mesoscale experiment, use mouse clicks to highlight the job to copy and an experiment to receive it. Use the "Job" & "Copy" commands at the top of the GHUI entry window of the UMUI system. Enter a suitable description and select an unused identifier. When the copy has completed, unhighlight those 2 lines and highlight the new one. Use "File" & "Open read/write" to open your new experiment.

Use window **subindep_Runlen**

```
Sub-Model Independent
-> Start Date and Run Length Options
```

to set your run start time and forecast length, making sure you do not go outside the timespan covered by your boundary data.

Go to window **atmos_Domain_Horiz**

```
Atmosphere
-> Model Resolution and Domain
--> Horizontal
```

and enter the 8 data values which specify your domain (see section 3.9.3). Set rimwidth the same as you set in the job generating your boundary data. The question about "mesoscale" is irrelevant as it only affects assimilation defaults. Also enter the number of land points in the land/sea mask as given by the ancillary creation job (see section 3.9.4).

If you have chosen a non-standard set of levels, go to window **atmos_Domain_Vert**

```
Atmosphere
-> Model Resolution and Domain
--> Vertical
```

and enter their eta half levels here - they must be identical to those specified for generating your boundary data.

If you have chosen a non-standard horizontal resolution, you should revise your choice of diffusion coefficients at window **atmos_Science_Onlevel**

```
Atmosphere
-> Scientific Parameters and Sections
--> Level-by-level Constants, Physical Constants
```

See section 3.8.3 on horizontal diffusion for help with this.

Check window **atmos_Assim_General**
```
Atmosphere
-> Assimilation
--> Parameters, Control
```
and select No assimilation, unless you have produced valid acobs files for your domain.

Under the section
```
Atmosphere
-> Ancillary and input data files
```
you can specify your initial data dump, boundary data file, and any ancillary files created for your new domain, eg:

- Window: **atmos_InFiles_Start**
  ```
  Atmosphere
  -> Ancillary and input data files
  --> Start Dump
  ---> Start Dump
  ```
  Specify initial dump file, and you will usually want to use the reconfiguration.

- Window: **atmos_InFiles_PAncil_Soil**
  ```
  Atmosphere
  -> Ancillary and input data files
  --> Climatologies & potential climatologies
  ---> Soil: VSMC, hydrological/thermal conductivity etc
  ```
  Specify soil ancillary file (if you have one), with "Configured" for each variable present (but "Not used" for Saturated soil water suction, unless multi-level hydrology has been selected).

- Window: **atmos_InFiles_PAncil_Veg**
  ```
  Atmosphere
  -> Ancillary and input data files
  --> Climatologies & potential climatologies
  ---> Vegetation
  ```
  Specify vegetation ancillary file (if you have one), with "Configured" for each variable.

- Window: **atmos_InFiles_OtherAncil_LBC**
  ```
  Atmosphere
  -> Ancillary and input data files
  --> Other ancillary files and Lateral Boundary files
  ---> Lateral boundary conditions
  ```
  Specify boundary data file (directory and filename from generating job), also specify rimwidth (eg. 4) and weights (eg. 1.0, 0.75, 0.5, 0.25). This weighted application of boundary data over several edge rows gives more realistic fields near the boundaries and better forecasts than just applying single boundary values to the edgemost points.

- Window: **atmos_InFiles_OtherAncil_Orog**
  ```
  Atmosphere
  -> Ancillary and input data files
  --> Other ancillary files and Lateral Boundary files
  ---> Orography ancillary file and fields
  ```
  Specify orography ancillary file, and select orography to be configured plus standard deviation and orographic roughness as appropriate. Operationally we allow the 8 edgemost boundary gridpoints to retain values interpolated from the initial data, to assist in the smooth application of boundary data.

- Window: **atmos_InFiles_OtherAncil_LSMask**
  `Atmosphere`
  `-> Ancillary and input data files`
  `--> Other ancillary files and Lateral Boundary files`
  `---> Land-Sea-Mask ancillary file and fields`
  Specify land/sea mask file and to be configured.

All other windows should be as for an ordinary forecast run.

Make sure you "Save" and "Process" before you "Submit" the job.

3.9.7 Advice

Having set up your new experiment, *test it with a short run* (but long enough to cover all important features, eg. STASH output or ancillary updating) and check the output, before you commit yourself to using large amounts of computer time for your full runs.

3.10 Atmospheric Tracers

Author: David Robinson / Peter A. Clark, Last Updated: 16 Apr 96

3.10.1 Introduction

The UM contains the facility to advect a number (29/18 for atmosphere/ocean at version 4.0) of 'tracers'. These are variables that represent the mass mixing ratio (nominally kg/kg, though since they are not used anywhere else in the model, this is of little importance) of a 'passive' material.

The tracer system is intended as a basis for people to test out aspects of the model's performance, or for 'private' applications, not as a mechanism for introducing new prognostic variables into the forecast. The tracers are thus referred to sometimes as 'free use' tracers to remind potential users that they should not write code which hard wires them into some aspect of the model. The system may be used as a way of marking particular airparcels to track them, or may be (and is by various groups) used as the basis for more involved chemical modelling by the addition of extra code.

The tracers are advected by the model winds, but using a different numerical method (of which there is a choice - see UMDP 10 [5]). The methods are designed to ensure that sharp gradients are preserved while keeping all concentrations greater than or equal to zero. This is particularly important when the tracer concentration is taken to represent a real concentration, especially when the concentrations are passed to a chemical model which calculates changes in concentration by chemical reaction, which would be highly confused by negative concentrations. The scheme may be regarded as being highly accurate, at least in comparison with the scheme used to advect the main model variables, but this accuracy comes with quite a high cost.

This section will cover the UMUI aspects of using tracers, some guidelines for getting them into the model (i.e. ancillary fields) and a brief introduction to aspects of the code as a start for people wishing to build on the system.

3.10.2 UMUI aspects

Tell the system you want to use tracers

For *atmosphere* tracers select window **atmos_Config_Tracer**

```
Atmosphere
-> Model Configuration
-- => Tracers
```

For users running the ocean or the coupled (Atmosphere/Ocean) model, there is also a list of *ocean* tracers to choose from in window **ocean_Tracer_UserDef**

```
Ocean GCM
-> Tracers
--> User Defined Tracers
```

Ocean tracers are not widely used yet and this note concentrates on atmosphere tracers.

Through the first question in both windows, select whether tracers are to be included in the Atmosphere model and/or the Ocean model.

After this question, there is a table that can be scrolled to select the tracers to be used. Tracers are selected by inserting one of the following values against the relevant tracer and the values (> 0) indicate how the tracer fields are to be included.

- 0 : Do not use the tracer.
- 1 : Include from an input dump.
- 2 : Configure from an ancillary tracer file.
- 3 : Update from aerosol climatology.

Notes: The chemical identification of the tracers is purely for the benefit of the stratospheric chemists, the biggest users up to recently, and has no relevance to the code. The main identifying numbers are the section 0 STASH item codes, which are needed when creating initial concentrations.

After the Tracer table, there is a question asking for the number of model levels to have tracers. This option was first added for the benefit of the stratospheric chemists so if you select a number of levels less than the total in the model *they are assumed to be at the top of the model.*

The final question selects whether the tracers should only be advected or whether they should be mixed in the vertical by the boundary layer scheme as well. It is possible, via private mods, to select a subset to be mixed, but the UMUI currently sets either all or none.

Tell the system what sort of tracer advection to use

There is currently only one version (1A) available. To advect atmosphere tracers this version must be included through window **atmos_Science_Section_Atradv**

```
Atmosphere
-> Scientific Parameters and Sections
--> Section by section choice
---> Atmospheric tracer advection
```

There is also a choice in this window whether to use the **Van Leer** or the **Superbee** limiter in the code. A discussion of the options for the limiter can be found in UMDP 11 [6].

Finally, there is a question offering to run the tracer advection scheme for thetal and qt. This option is experimental and can be used particularly for mesoscale applications. Potential users are advised to contact NWP Division before using this option.

Tell the system where to get it's initial data from

If data are to be introduced from an external ancillary file (normally the case) the directory and filename are specified in window **atmos_InFiles_OtherAncil_TracAer**

```
Atmosphere
-> Ancillary and input data files
--> Other ancillary files and Lateral boundary files
---> Atmospheric tracer advection
----> Tracer and aerosol ancillary file
```

3.10.3 Initial Condition Files

Initial data (unless, of course, they already exist in the dump) are introduced at the reconfiguration step and must therefore be available in the form of an ancillary file. Creating such a file is, in fact, relatively straightforward, but depends, of course, where the data originate and how they are generated. It is therefore impossible to outline a general method. Programs exist to generate such files from pp format files, and the user is referred to the ancillary file group in NWP Division for advice. Points to note, however, are:

- Ensure that the STASH, pp and grid codes are correct.
- The reconfiguration step checks that the verification time of the data matches that of the dump being reconfigured into. It is therefore difficult to include a general 'test blob' without recreating the ancillary field. A modset can be generated to overcome this.
- It is important that the level dependent constants for the levels and the level thicknesses match the dump.

3.10.4 Model aspects

Once inside the model dump, tracers will be advected and may be output by STASH using the appropriate variables in section 0. For those who simply wish to use tracers as markers this will suffice. For those who wish to use the tracer variables as the basis of, say, a chemical or dispersion model, hooking in your own routines is straightforward.

The tracer data are stored in the dump array D1 on the p grid, the number of levels being defined by TR_LEVELS and the number of tracers by TR_VARS. The first data point on each level is pointed to by the pointer JTRACER(LEV,JVAR), where LEV refers to level and JVAR to the tracer variable. Each level is stored immediately after the last, so it is safe, for example, to pass tracer data to a subroutine expecting multi-level data by referring, in the CALL statement, to D1(JTRACER(1,JVAR)). It is thus very straightforward to pass tracer arrays to 'physics' routines from the control level.

Note, JVAR goes from 1 to TR_VARS and they are ordered as selected in the UMUI. The 'true' identity can be found by looking in the array A_TR_INDEX, stored in the common block ATRACER which is declared in the COMDECK CTRACERA. This contains the 'local' (JVAR) value for each tracer in use. It is thus feasible (though probably unnecessary) to write code which uses absolute tracer identities.

3.10.5 Additional remarks

A few systems have been built using the tracer variables which the potential user should be aware of, as some UMUI support exists for these which may be of use for experiments. Systems currently known about are:

- Stratospheric/middle atmosphere chemistry. From UM version 3.4 the facility exists to assimilate data from atmospheric measurements of chemical species. The user is referred to members of the appropriate group for information.
- Investigation of the impact of aerosols on climate. Some UMUI support for incorporating surface source terms of sulphur dioxide and hydrogen sulphide, plus initial or fixed concentrations of aerosol concentrations.
- From UM version 3.4 an aerosol variable exists which is advected using the tracer scheme, and may (optionally) have sources and sinks applied. This is used to estimate visibility, and may be adjusted by assimilation of visibility data. In limited area models the boundaries are not updated from the boundary conditions file.

3.11 Science Options

Author: Rick Rawlins, Last Updated: 16 Feb 96

3.11.1 UM Releases

The Unified Model partly resembles an operating system in that it has periodic releases. Each release is largely independent; it has its own version of the source code, scripts, executables, user interface and control files. It is also largely fixed once released. Unlike an operating system, users have access to several versions of the UM at any one time, they also have the ability to change it. UM versions are defined by a two level identifier, eg UM version 4.1 would follow UM version 4.0. A new first level identifier is chosen when there is a very significant change to the overall scientific or system structure, eg the move from 3.4 to 4.0 constituted a change from a mainframe user interface to the X-windows UMUI.

The UM tends to progress by evolution, and modifications to source code (see section 3.19) can be developed and made available to other users between releases.

3.11.2 Sub-models, Internal Models and Sections

From a scientific point of view, a UM experiment can be divided into an hierarchy of components forming a composite structure that defines the model as a whole. The model may be composed of one or more sub-models, such as atmosphere or ocean sub-models, which each have their own data space, and consequent separate descriptions of model state variables. Within a sub-model there may be one or more internal models, such as the atmosphere and slab internal models within the atmosphere sub-model, which are distinct entities with their own time-stepping sequence. Sub-dividing further, each internal model is made up of a number of separate sets of calculations, such as for radiation or the boundary layer within the atmosphere internal model, and these are termed 'sections'.

The organisation of code is projected onto the idealised picture above such that each sub-model allocates its own state variables within separate definitions of the main data array, ie D1 in the Fortran code, and generates separate dumps of data. Below this level there are scientific sections (for example, section 1 is short-wave radiation for the atmospheric internal model) which are used in 2 ways:

1. to group related routines together in practical chunks, for source code management and ownership, and for partitioning pre-compiled object code;
2. to specify groupings of diagnostic variables calculated in these routines, to be referenced by the internal addressing and diagnostic system: STASH (see section 3.16).

For example, scientific sections for the atmosphere internal model can be accessed from the UMUI via

```
Atmosphere
-> Scientific Parameters and Sections
--> Section by section choices
```

In addition there are non-scientific sections of code which are independent of internal models, such as section 95 for I/O operations, which conveniently package together related routines, but have no application for definitions of variables. At UM version 4.0 and earlier, there is no overlap of section numbers between internal models, but this is likely to change at future versions when larger numbers of internal models need to be accommodated.

The full complexity of the relationship between internal models and sub-models only needs to be considered for coupled applications of the UM. In most cases the description is much simpler, for example the atmosphere

model is equivalent to the atmosphere sub-model + atmosphere internal model, and the terms are often used interchangeably.

3.11.3 Section Version-Releases

From the UMUI, you will note that some sections have several alternatives, defined by version and release, abbreviated to v<r>. This is to allow groups of users to have access to different flavours of these sections. For example some users need to be able to access the latest developments in gravity-wave drag, others need to be consistent with work they started some time ago. This system also allows externally written versions of the sections to be imported for testing.

For the UM as a whole, the terms 'version' and 'release' are used synonymously. However for labelling alternative code within the same section, their meaning is more specialised. Every allocated section contains at least one version of the code, normally version 1A (i.e.version 1, release A). When there are significant conceptual differences, these are denoted by a new version number (1,2,3 etc). Smaller differences would be denoted by a change in the release letter (2A, 2B, etc). The UMUI encodes the user's choice (see section 3.19) into *DEF logical switches and these are placed in the UPDEFS control file produced by the UMUI. These can also be seen in the source code at the head of each science routine, which provides the mechanism for automatic inclusion of the correct modules at compile time. In more detail, *DEFs are used in a model run:

- To define the object library elements that need to be extracted from a pre-compiled object library;
- To define which sections of the source code are written to the compile file
  1. if there is no pre-compiled object code, or,
  2. if modifications to source code are being included;
- In addition, the v<r> chosen can have an effect on the diagnostic variables available to the user from that section (see the appendix of UMDP C4: Storage Handling and Diagnostic System (STASH) [19]).

A section v<r> is defined by a series of DECKs in the source code, but note that some DECKs are shared across several v<r>s. The naming convention for the *DEFs define internal model, section and it's v<r>: A01_2B would be version 2B of section 1 (SW radiation) in the atmospheric internal model.

Ideally, each section of code would form an independent module and different v<r>s could be selected with any combination of choices for other sections. However in practice the assumptions behind some calculations for different sections are related, so that it only makes sense to use certain combinations of v<r>s. Guidance is given in help panels of the UMUI when a choice of different schemes is presented.

3.11.4 The Frozen Model for Met. Office users

One v<r> for each section is denoted the frozen version. It is the one defined as the default climate version in the UMUI. This v<r> must give the same results from one release of the model to the next. Even if an error is found, code changes to this v<r> can only be made as long as they do not affect the results of prognostic variables. This rule ensures that long running climate models can be repeated.

Periodically, the definitions of the frozen v<r>s for all sections of the model are reconsidered, thus defining a new frozen model (although modifications may be found to be necessary during the testing period). New v<r>s are chosen for the new frozen model, other v<r>s are kept but corrected. When a large number of corrections and new developments have become enshrined in the code, a change in the highest level qualifier of the UM version would be considered, ie a move to UM Vn5.0. Models defined by the frozen section

v<r>s are used for testing new releases of the UM, they should give the same results down to the bit level. On exceptional occasions when these rules are broken, users will need to be informed.

This topic is covered further in UMDP 4: Maintenance of frozen versions of the UM for climate users [4].

3.11.5 Private Modifications

The above rules seem a bit restrictive. However, this is not a problem as Met. Office or external users can modify source code in whatever way they like to make personal changes. In addition facilities exist to add local definitions of user-supplied prognostic and diagnostic variables, so that they can be processed through the dumping and diagnostic systems with only minor changes of code needed (see UMDP C4 [19]).

3.11.6 Going Public

If Met. Office developers are intending to make their changes permanent at the next release of the UM, they need to think hard about the v<r> issue. If the modification affects the results of a section they should consider the other users of that v<r>. Can they all accept the change? If not, and especially if it is a frozen v<r>, then they should try to switch the feature in and out with FORTRAN control in such a way as to allow the same results to be obtained for those who require it. If the changes are extensive, then this may not be possible. In this case whole new DECKs will need to be written for some or all of the section and assigned to a new v<r>. The v<r> related *DEFs of the new, and shared DECKs will need to be re-considered.

3.11.7 The Kept Version of the UM

One version of the UM is designated the kept version, for each frozen model. This UM version is kept on line at the Met. Office and maintained for a long period of time (as space permits). It can be a good choice for those doing experiments that take a considerable time to complete. The alternative is to try to keep up with releases of the UM, either as they become available or as the previous one becomes obsolete. The second approach allows users access to any extra features of the new release and also ensures that the new releases are being tested in their model configuration, but it is recognised that this can involve a reasonable amount of effort.

Portable versions of the UM will map onto the definitions of UM versions given above, but not every version released for Met. Office users would necessarily be packaged as a portable model for external release.

3.12 Atmospheric Model

The Atmospheric Model is one of the sub-models available within the Unified Model. This section will contain information on how to configure and use the Atmospheric Model. Unfortunately, this information was not available for this issue of the User Guide.

3.13 Ocean Model

The Ocean Model is one of the sub-models available within the Unified Model. This section will contain information on how to configure and use the Ocean Model. Unfortunately, this information was not available for this issue of the User Guide.

In the meantime, information on the Ocean Model can be found in the following papers:

- UMDP 40: The Ocean Model [10]
- UMDP 41: Ocean Model Mixed Layer Formulation [11]
- UMDP 42: Penetrative Solar Radiation [12]
- UMDP 48: Lateral Boundary Conditions in the Ocean Model [13]
- UMDP 50: Application of Surface Heat and Fresh Water Fluxes [14]
- UMDP 51: Ocean Model Isopycnal Diffusion Scheme [15]
- UMDP 57: Knudsen Code for Density Coefficients [16]

3.14 Slab Model

The Slab Model is one of the sub-models available within the Unified Model. This section will contain information on how to configure and use the Slab Model. Unfortunately, this information was not available for this issue of the User Guide.

3.15 Atmosphere-Ocean Coupled Models

Author: Tim Johns, Last Updated: 7 Feb 96

3.15.1 Overview

The present design of the model control levels supports two-way coupling between:

(a) Atmospheric submodel and full oceanic submodel (including seaice)

(b) Atmospheric submodel and simple slab oceanic submodel

Future plans for the development of the UM include an expanded coupling concept based on the idea of multiple submodels (eg. atmosphere, ocean, seaice, wave, atmospheric chemistry, land/ocean biology, etc) with greater flexibility and modularity of coupling between them.

In order to achieve coupling in general, information is passed periodically from one submodel to another. This information may be in the form of instantaneous values (eg. presently predicted SST from the ocean model), or time-averaged over the period used for coupling (eg. the daily average solar energy flux into the ocean surface computed by the atmospheric submodel).

3.15.2 Timestepping in Coupled Models

A well-defined information-passing sequence is necessary to carry a coupled model forward in time, since each submodel is dependent on other submodels for forcing or boundary conditions. In the case of an atmosphere-ocean coupled model, the convention in the UM is that the atmospheric submodel is integrated first, atmosphere-ocean fluxes are computed and passed to the ocean/seaice submodel, the ocean/seaice submodel is integrated next, and new ocean/seaice surface variables are passed back to the atmospheric submodel to enable the cycle to be repeated. The period over which the cycle repeats is called the *coupling period*, and this approach is called *asynchronous coupling* because only one component of the model is being integrated at a time. There are alternative ways of coupling in which the submodels might be integrated in parallel, which might be more suited to highly parallel computer hardware. This *parallel coupling* approach requires additional synchronisation calls in the code and may be explored in later stages of the *Submodels* project.

Note: It is common practice to use a 1-day coupling period in the coupled atmosphere-ocean configuration, but this can easily be changed if desired.

3.15.3 Interpolation Between Submodels

In general, the spatial grids of two submodels connected by coupling may not be congruent, although they are congruent for some configurations in common use at the moment. Interpolations or area-averaging will need to be applied to coupling fields if the grids are not congruent. This operation is carried out as part of the internal coupling process in the model, with options as to the method used in some cases.

3.15.4 Special Ancillary Forcing for Coupled Models

In general, coupled models require fewer ancillary fields to be supplied than single-component models (eg. atmosphere-only or ocean-only), since the model predicts many of the fields which otherwise need to be specified as forcing or boundary conditions. However, atmosphere-ocean coupled models typically need to be calibrated against various reference climatologies (in so-called *calibration* runs) before they can be used to run prediction experiments. In the present atmosphere-slab-seaice configuration, these calibration fields

comprise sea surface temperatures, ocean currents and sea ice distribution. In the full atmosphere-ocean-seaice GCM, calibration is performed against reference sea surface temperatures and salinities, but the model is now sufficiently good that it is increasingly being run without such an initial calibration procedure. As a result of the calibration process, ancillary fields are derived which are used as constant (seasonally-varying) forcing terms in subsequent runs to encourage the model to give a control climatology close to the reference climatology. These derived fields are referred to as *flux adjustments* or, in the case of the slab model heat corrections, *heat convergences*.

3.15.5 Examples of Atmosphere-Ocean Coupled Models

Atmosphere-Ocean General Circulation Coupled Model

This version of the model, running on a global domain with a seaice submodel embedded in the ocean submodel, is the main configuration used for climate change simulations. The technique of *flux adjustment* is used in some production experiments to suppress the problem of climate drift which can occur in models of this type. Some experiments are also run with flux adjustments omitted.

Atmosphere-to-Ocean Coupling Fields

(i) Penetrative solar flux into ocean

(ii) Non-penetrative solar flux plus other heat fluxes into ocean surface

(iii) Precipitation minus evaporation net fresh water flux into ocean surface

(iv) River runoff net fresh water flux into coastal ocean outflow points

(v) Atmospheric wind stress into ocean surface

(vi) Wind mixing energy flux into ocean near-surface mixed layer

(vii) Net heat flux from atmosphere into seaice

(viii) Net snowfall minus sublimation onto seaice

Note: (vii) and (viii) are only passed if the seaice submodel is included.

Ocean-to-Atmosphere Coupling Fields

(i) Ocean sea surface temperature and surface currents

(ii) Seaice fractional coverage within gridbox and mean seaice thickness

Atmosphere-Slab Coupled Model

This version of the model always uses a global domain, and usually includes a seaice submodel as part of the slab ocean. It is primarily used for short climate sensitivity experiments, and for examination of equilibrium climate change responses in comparison to transient responses from the full model.

Atmosphere-to-Slab Coupling Fields

(i) Net solar flux plus other heat fluxes into slab ocean

(ii) Net heat flux from atmosphere into seaice

(iii) Net snowfall minus sublimation onto seaice

Slab-to-Atmosphere Coupling Fields

(i) Slab ocean temperature

(ii) Seaice fractional coverage within gridbox and mean seaice thickness

3.15.6 Coupling Information Required on UMUI Panels

This falls logically into 3 parts.

1. Which submodels are included in the configuration?
   Window: **smcc_Model**
   `Sub-Model Configurations and Coupling`
   `-> Sub-Model Inclusion Switches`

2. *a)* What is the coupling period and interpolation method for atmos-ocean GCM?
   Window: **smcc_AO_Coupling**
   `Sub-Model Configurations and Coupling`
   `-> Atmosphere & Ocean GCM coupling`

   b) What is the coupling period for atmos-slab GCM?
   Window: **smcc_AS_Coupling**
   `Sub-Model Configurations and Coupling`
   `-> Atmosphere & Slab-ocean coupling`

3. Other detailed information (ocean and slab-related) which determines the flavour of the coupled configuration (eg. flux-adjustments included/excluded, calibration/control run, frequency of updating related ancillary fields, etc.).
   Window: **ocean_Science_SurfForce_Haney**
   `Ocean GCM`
   `-> Scientific parameters and sections`
   `--> Surface Forcing`
   `---> Haney Forcing`
   Window: **ocean_Science_SurfForce_Flux**
   `Ocean GCM`
   `-> Scientific parameters and sections`
   `--> Surface Forcing`
   `---> Flux Correction`

Window: **ocean_InFiles_PAncil_SstSss**

```
Ocean GCM
-> Input Files
--> Climatologies and potential climatologies
---> Reference SST, SSS, Air-Temp & Ice-Depth
```

Window: **ocean_InFiles_PAncil_CorrHeatSal**

```
Ocean GCM
-> Input Files
--> Climatologies and potential climatologies
---> Flux Correction fields
```

Window: **slab_Science_Section**

```
Slab Ocean
-> Science and scientific sections
--> Slab section 40. Configuration choices
```

Window: **slab_InFiles_PAncil_HeatCon**

```
Slab Ocean
-> Ancillary files
--> Heat convergence
```

Window: **atmos_InFiles_PAncil_Calib**

```
Slab Ocean
-> Ancillary files
--> Calibration fields
```

3.16 Diagnostic Output (STASH)

Author: David Robinson, Last Updated: 16 Apr 96

3.16.1 Introduction

The output of diagnostics from the UM is set up using the Spatial and Temporal Averaging and Storage Handling (STASH) system. STASH is a very flexible system that allows users to obtain diagnostics on a timestep to timestep basis and to process diagnostics in both time and space. Diagnostics include intercepted fields generated as the model runs and derived quantities. Users can chose from a wide range of diagnostics available or interface new diagnostics into the system.

Further details on the STASH system can be found in UMDP C4 [19].

3.16.2 STASH in the UMUI

In the UMUI, there is a main STASH panel available for each internal model currently available - Atmosphere, Ocean and Slab. The path to this panel is:

```
Atmosphere OR Ocean GCM OR Slab Ocean
-> STASH
--> STASH, Specification of Diagnostic requirements
```

This panel is where the user will select the diagnostics required in a model run. The bottom part of the panel lists the diagnostics required. Each diagnostic will have three profiles attached to them and the profiles appear in the top half of the panel. If there are no diagnostics or profiles then all the boxes in this panel will be empty.

In the middle of the panel, there is a HELP button. Clicking here will bring up a menu leading to help pages on STASH, Diagnostics and Profiles. Users should refer to the help page on STASH before doing any STASH processing, especially those entering STASH for the first time. All the windows involved with STASH have HELP buttons which provide detailed information for each window.

It is recommended that the user defines the model configuration in the UMUI before entering STASH. This is because the availability of some diagnostics depend on answers to questions in other parts of the UMUI.

3.16.3 Setting up the Diagnostic List

The first task for most users will be to sort out what diagnostics are required in the list. Detailed information on the diagnostic list and how to manage it through action buttons can be found through the help page on diagnostics.

3.16.4 Profiles

After setting up the diagnostic list, the user needs to consider the three profiles - Time, Domain and Usage - to be attached to each diagnostic. The profiles are identified by their names which normally begin with 'T', 'D' and 'U' to help recognise the type of profile. This naming convention is not compulsory.

Detailed information on the profiles, how to manage them through action buttons and how to attach them to the diagnostics in the diagnostic list can be found through the help page on profiles.

Time Profiles

They determine when a diagnostic will be output and the period over which time processing on any diagnostics is done (eg, accumulations or means).

- For diagnostics that involve time processing (Time Accumulations, Time Means, Time Series or Max/Min value in a period), two times must be entered. The *first* is the sampling frequency and the *second* is the period for the time processing. As an example, if an accumulation period of 6 hours with a sampling frequency of one timestep, the output will be the sum of the value at every timestep over a period of six hours. If an accumulation is to take place throughout the run then the accumulation period should be set to -1.
- Diagnostics can be output at any time ; Regular or irregular output times can be selected. For *regular* output a start time, end time and a frequency are required. If output is required at regular intervals for the entire length of the run the end time should be set to -1. For *irregular* output, the times are entered in the window.
- For time processed diagnostics, the output times must coincide with the end of any time processing period. Take a six hour accumulation period for example, the output times can be at the end of any accumulation period, ie. after 6,12,18,24... hours. So it is possible to output a six hour accumulation every 24 hours; the output will contain accumulated data for the periods 18-24 hours, 42-48 hours and so on. The frequency of output times must not be shorter, but not need be the same as, the time processing period.
- For time series diagnostics, time and domain profiles for time series must be set up.

Domain Profiles

They determine the geographical region and level(s) for which the diagnostic will be output. Four windows are involved in setting up a domain profile and the UMUI will start with window **atmos_STASH_Domain1**. At the bottom of each window, there are three out of the four - LEVS, HORIZ, PSEUDO, TSERIES - buttons which will take the user to one of the other three windows.

Through window **atmos_STASH_Domain1** (LEVS button), the level type is selected. Depending on the choice, the user will be prompted to enter more information, for example, choosing model levels will prompt the user to enter whether a range or a selection of levels is required.

Through window **atmos_STASH_Domain3** (HORIZ button), the following are selected:

- The geographical area. There are a number of standard areas to choose from. The user can also select an area by specifying lat-long or gridpoint rectangle. Where necessary, the area is rounded up to match full model grid boxes and diagnostics could be output for a slightly greater area than that specified.
- Grid points to be included (ie, all, land or sea)
- Any meaning of the data (ie, in zonal, vertical, meridional or horizontal). Meaned data saves time and disk space.
- Any weighting of the data (ie, horizontally or by volume or by mass)

Through window **atmos_STASH_Domain2** (PSEUDO button), a pseudo level type is selected. This allows a fourth dimension (such as LW or SW bands) which is required with a few fields. This is not often used and is normally set to 'No pseudo level dimension'.

Through window **atmos_STASH_Domain4** (TSERIES button), the domain profile is defined for a Time Series diagnostic. A list of model grid-points and levels allows the user to specify the exact extent of the area of model data that is meaned in order to form a single value for a particular point in time for each domain in each domain profile. If desired, just one model grid-point can be selected, e.g. to compare model data with data from individual stations.

Usage Profiles

They specify which output unit (or PP-file) the diagnostic will be stored in. Diagnostics can be sent to more than one output unit by repeating the diagnostic in the list and attaching different usage profiles.

The unit numbers for the PP files are in the range 60-69. Output written to units 60,61,...,69 are stored in files with the extension .pp0,.pp1,...,.pp9 where PP files are not reinitialised. As an example, output sent to unit 64 from experiment ABCD, job Z will go to the file abcdz.pp4. Reinitialised PP files have the extension .pa,.pb,...,.pj and include a model date calculated automatically.

Usage profiles are also used to direct output to files in connection with climate meaning. For further details, see section 3.17.

Not all diagnostic fields go into a PP file. A number of fields are stored internally to be passed between different sections of the UM during a model run. Through the Usage profile those fields are given a TAG number to enable the UM search for these fields by their TAG number when required. The help page on Usage profiles provides more information on attaching Tag Numbers to diagnostic fields.

3.16.5 The STASHmaster file (SMF)

This file contains information on all diagnostics available to the UM. For every prognostic or diagnostic, there is a record which is described in full in UMDP C4. Typical information stored is what grid and levels (model or pressure) the data is stored on and how the data should be packed. It is the information in this file that the stash panels in the UMUI use to verify whether any diagnostics and its profiles in the diagnostic list have been set up correctly.

Any prognostic or diagnostic used in the UM must exist in this file otherwise it must be provided through an USER STASHmaster file.

The USER STASHmaster file (USMF)

This file enables an user to add new prognostics, diagnostics or ancillary fields if they do not exist in the SMF. It can also be used to correct or test changes to a record in the SMF. USMFs are specified in the window **atmos_STASH_UserDiags**

`Atmosphere`
`-> STASH`
`--> Specification of User Diagnostics`
(similar windows exist in the `Ocean GCM` and `Slab Ocean` sections)

- Several USMFs can be attached. Each file should relate to individual modsets.
- Any USMF must be set up and attached before entering STASH.
- The USMF must exist on the same platform as the UMUI.
- UMDP C4 [19] (page 13) provides all the information that can be set in a record for each field.

- A template USMF to start from can be found in the help panel for this window.

Adding any new fields usually requires extensive changes to the UM code. A system has been set to allow the user add new fields and use them as ancillary fields without the need to modify any code for the UM to recognise and get these fields into the model (Code changes are still required to integrate the data in the model). These fields are also known as 'User Ancillaries'. This involves setting up a USMF using Stashcodes (under section 0) which have been reserved:

- 301-320 : For atmosphere single level ancillaries
- 321-324 : For atmosphere multi-level ancillaries
- 331-340 : For ocean single level ancillaries
- 351-354 : For ocean multi-level ancillaries

Full details on 'User Ancillaries' can be found in section 3.6.7.

3.16.6 Initialisation of User Prognostics

After the user has provided extra records through a USMF, it is necessary to initialise any *prognostic* fields for a run. This is done in the window **atmos_STASH_UserProgs**
`Atmosphere`
`-> STASH`
`--> Specification of User Prognostics`
(similar windows exist in the `Ocean GCM` and `Slab Ocean` sections)

In this window, the user has a wide choice on how to initialise their prognostic fields.

3.16.7 STASH Macros

For the atmosphere model only, there are a number of STASH macros set up. A STASH macro is an internal list of STASH diagnostic requests with profiles attached. A list of macros are available for selection in the UMUI section:
`Atmosphere`
`-> STASH`
`--> STASH macros`
There are other STASH macros associated with coupling or including the assimilation. These macros are selected for inclusion in different UMUI locations.

If a macro is included in your job, the macro asks STASH to generate the diagnostics either in a PP file or internally during a model run. The help page for each macro will inform the user where the diagnostics go. If users need to add extra diagnostics to those in the macro (this should be rare), this can be done through the STASH processing section and care should be taken with the Usage profile to ensure the diagnostic goes to the same destination.

The full list of diagnostic fields set by the macro can be browsed in the STASHC file after the job has been processed.

3.17 Climate Meaning

Author: K. Rogers, Last Updated: 18 Mar 96

3.17.1 Introduction

Climate runs are very long runs of the Unified Model that can automatically resubmit themselves, and are divided into conveniently-sized chunks (or resubmit increments) such as one or two years. They have a built-in mechanism that makes them restartable from a safe restart point linked to the meaning periods. This means that if there is a system crash the model can be restarted from the last safe restart point. The run can also be continued at a later date beyond the original run target-end date.

These runs are different from forecast runs in that the initial conditions as defined in the start dump are not that important compared to the ancillary files that provide the boundary conditions and the forcing parameters. Also in forecast runs the forecast must be produced in the minimum time and it does not matter that results are not reproducible. With climate runs it is important that runs bit compare so that parts of a long run can be repeated with extra diagnostics and to ensure an experiment is consistent with a previous one, since last bit differences can make a significant difference to the climate produced by a run. During a climate run, certain properties have to be conserved, such as the mass of the atmosphere, but strict conservation is less important for the short timescales of a forecast run.

The following sections describe the climate meaning system and how to setup diagnostics that use this system.

For more information on the Unified Climate Model see Unified Model documentation papers:

- UMDP 1: Introduction to the Unified Forecast/Climate Model [1]
- UMDP C0: The Top Level Control System [18]

3.17.2 Climate Meaning System

The climate meaning system allows the user to specify up to four 'meaning periods' and the model automatically produces means of the selected variables over each of these periods. For example, a climate modeller could specify mean fields over 30 days, 1 season (3 months), 1 year and 10 years. Note that the system assumes that model years are 360 days long for simplicity. The last safe restart point for the model will be at the start of the last period 1 mean eg. the start of the month.

The basic unit of time of the UM is the 'dump frequency', typically once a day. This is how often fields are written out from D1, the main data array that holds primary (ie. prognostic and ancillary), diagnostic and secondary fields, to various kinds of dump files. Fields can be processed in various ways within each day (see section 3.17.3 on diagnostics below), but all output files for periods longer than the dump frequency are means of these daily dumps.

Instantaneous dumps (also known as restart dumps) have filenames of the form $RUNID.da..., eg. cbdjia.daj34e0. When things go wrong, it is possible to continue the run from one of these instead of making a new run. It is conventional to choose to produce a restart dump every day, delete them when a new one is produced, and archive one at every period 1 mean, usually the first one of every month, using the UMUI to set this up.

Fields from D1 are also added to partial sum mean dumps, which have names of the form $RUNID.apstmp1 for atmosphere fields and $RUNID.opstmp1 for ocean fields. These files are usually deleted automatically at the end of a run, since they reside in a temporary directory. However if the run stops part way through a meaning period the files are copied to a permanent directory. At the end of every period 1 time length, the

completed period 1 partial sum mean dump is copied to the period 2 partial sum mean dump, and so on for the other meaning periods. These further partial sum mean dump files have a different naming convention from the period 1 partial sum dumps, viz. $RUNIDa_s2a and $RUNIDo_s2b etc. where the letter 'a' or 'o' shows whether it is an atmosphere or ocean file, the number shows which period the mean is for and the last indicating letter shows whether the file is for writing to or reading from. These files are not deleted routinely at the end of a run and are held in permanent disk space.

The last type of dump file that may be produced is a mean dump. The filename convention for these is $RUNID.dm... where the letter m indicates that the dump is meaned over a month, t for 10 days, s for a season, y for a year etc. If meaning is done over less conventional timescales the filename convention is $RUNID.d1... where the number 1 indicates that the mean dump is for a period 1 mean; similarly for other mean periods. These mean dump files are not normally archived.

For more information on the meaning system see Unified Model documentation paper:

- UMDP C5: Control of Means Calculations [20]

3.17.3 Setting Up Mean Diagnostics

There are two ways of producing mean diagnostics in the Unified Model system. Most people use the first method (see section on General Meaning System below), from which a wide variety of diagnostics can be obtained. The second method (see section on Selected Means of Instantaneous Values below) uses diagnostics that are calculated anyway if the meaning system is switched on and so involves no extra overhead, but only provides means of instantaneous prognostic variables at the dump time eg. midnight.

Anyone setting up diagnostics for a climate run is strongly advised to copy a standard climate experiment containing diagnostics, so that suitable time and usage profiles together with most commonly used diagnostics are already set up. The notes below give an overview only and are not adequate for setting up diagnostics from scratch.

For more information on the diagnostic system see Unified Model documentation paper:

- UMDP C4: Storage Handling and Diagnostic System (STASH) [19]

General Meaning System

Any diagnostic can have a number of processes applied to it at a frequency of one timestep up to the dump frequency (usually once a day). Then the value held for the day can further be meaned over the different meaning periods. The processes that can be applied include meaning, extracting an instantaneous value, accumulating and calculating maximum/minimum values, all every nth timestep. The frequency is often every timestep but it may be more appropriate for it to be say every 3 timesteps if the model only does relevant calculations every 3 timesteps (as with certain radiation diagnostics for example).

Extra space has to be allocated within the D1 array for these diagnostics and they involve extra processing.

To set up the diagnostics:

1. Open the main stash panel in the UMUI:
   `Atmosphere`
   `-> STASH`
   `--> STASH, Specification of Diagnostic requirements`
   For ocean and slab diagnostics go to the equivalent panel within the `Ocean` or `Slab` section.

2. To set up a time profile press the 'Copy Profile' button to copy an existing time profile and then 'Edit Profile' to edit it. Specify the 'time mean' option and how often you want to take a sample of the diagnostic for meaning (the 'frequency'). The 'output times' specifies the points in the run over which the diagnostic should be produced as a range or a list. Alternatively you can select to accumulate, take an instantaneous value or max/min value over the dump period from the same window.

3. If you want to mean over a meaning period in addition to meaning over the dump frequency (eg. a day) you need to set up the usage profile as follows. Select 'Dump store with climate mean TAG' and then specify which of the 4 meaning periods the diagnostics should be meaned over. Then ensure that all the diagnostics you want meaned use this usage profile in the main stash panel.

4. Select the diagnostics you want to use from each section: Press the 'Load New Diag' button in the main stash window. Double click on a section number to look at all the available diagnostics for that section and double click on individual diagnostics to select them. All selected diagnostics are shown in the list at the bottom of the main stash panel. Then double click on the time/domain/usage profile for each diagnostic to pick up the highlighted profile of each type from the top part of the panel, changing the highlighted profiles as appropriate.

Selected Means of Instantaneous Values

These diagnostics are only used for period means of instantaneous prognostic values at each dumping period (eg. each day) or diagnostics directly calculable from these, so there is a limited list of diagnostics to select from, eg. 26 for atmosphere. The values used in these means are the field values at midnight (since that is when the dump file gets written out each model day). The contents of the dump file get added to the partial dump file each day until the period 1 mean is reached. Then the contents of the file are meaned.

To set up the diagnostics:

Go into the main stash panel and press 'Load New Diag'. Double click on sections 21-24 or 41-44 as appropriate (see below) and then select the diagnostics you want by double-clicking.

Use the following section numbers:

	Model Type		Diagnostics
	Atmosphere	Ocean	Called
Period 1 means	21	41	CM1:...
Period 2 means	22	42	CM2:...
Period 3 means	23	43	CM3:...
Period 4 means	24	44	CM4:...

These sections are only called at the relevant meaning periods.

3.17.4 Output to Reinitialised PP Files

If diagnostics are not to be meaned using sections 21-24 and 41-44 in the climate meaning system and output to mean PP files, they can be output to reinitialised 'daily' PP files (or the same diagnostics can be output in both ways). For example the following types of diagnostic are frequently requested:

1. Instantaneous eg. every 12 hours. Requires no memory overhead.

2. Means over any specified time length x. Stored in D1 so requires increase in memory.

3. Maximum or minimum values over a time length x. Requires space in D1.

4. Accumulation over a time length x. Requires space in D1.

If the same diagnostics are requested as mean diagnostics for the period 1 mean and the time length x is the dump frequency, then no extra memory is required to produce the above diagnostics, in addition to that required to hold the climate mean values.

It is important to check how often these files are reinitialised in window **subindep_PostProc_PPInit**

```
Sub-Model Independent
-> Post Processing
--> Initialization and processing of mean & standard PP files
```

Typically they are reinitialised every period 1 mean, but may need to be reinitialised more frequently if the files are large or there is a shortage of disk space. Daily PP files have names of the form:

$RUNID[ao].p[a-j]date

where [ao] refers to atmosphere or ocean and the [a-j] are the different output streams corresponding to unit numbers 60-69. eg. cabcda.pbj1feb is an atmosphere PP file outputting on unit 61 for the month after 1st Feb 1991 (using the absolute time standard naming convention).

3.18 Automatic Post-Processing for Climate Runs

Author: Linda Wiles, Last Updated: 18 Mar 96

3.18.1 Introduction

Climate mode integrations carried out on powerful computers can generate output at rates which make it necessary for data to be archived and housekeeping tasks carried out as the model is running. Failure to do this can lead to disk space shortages.

The model initiates output post processing by sending output processing requests direct to an independent 'slave' process, which acts as a server for the model. A pipe connects the model to the server, and requests are read by the server down the pipe in the form:

```
%%% filename ARCHIVE/DELETE file_type
```

where '%%%' is a pattern the server can recognise as indicating that the following information is a request to either archive or delete the data. The four file types are dump, pp, mean pp and boundary data.

3.18.2 Archiving system at vn4.0

These scripts are mainly used at the Met. Office, but potentially could be used on other sites by inserting site-dependent copy commands and variables in the parts where $UMMACHINE is not set to "METOCRAY". This would enable superceded dumps or PP files to be deleted and data files to be copied (togther with lists of files to be archived) to another directory or machine while the run is continuing. A separate archive server would need to be developed to move the data to more permanent storage.

Main Functions of the System

- Copy model pp files, restart and dump files to another unix system or archive system (or to the front end system as at the Met. Office)
- Disk management of the current disk files generated by the model i.e. delete files on current system as run proceeds
- Release users own archiving scripts

At vn4.0 the archive system generates 'trigger files' and the archiving jobs are built on the secondary system using data contained in the trigger files.

- Upon successful data file transfer, a 'trigger file' is updated with details such as the secondary system dataset name, and the expiry date of the archived file.
- Upon reaching a maximum file number per trigger file, which is set in the UMUI for each type of file, the trigger file is transferred to the secondary system.
- An Archive Server Function is active on the secondary system and deals with the generation and submission of archive tasks. Such tasks examine the trigger file contents, then carry out archiving procedures. At the Met. Office, the archive server runs on the IBM MVS system.

The system performs the following additional tasks

- Execute user supplied output processing scripts when required (e.g. for the operational suite at the Met. Office).
- Update model output processing history variables as requests are dealt with and recreate output processing history file on completion of each request.
- If the server dies or a transfer error occurs, a message is sent to the model requesting it to stop. This prevents files building up on the computer running the model. In this case, requests from the pipe are sent to a '.failure' file in the users experiment directory. This file is read when the model is restarted, tidying up files automatically, except for some checks that need to be made after a crash.

3.18.3 User instructions for Automatic Post-processing of Climate Runs

The trigger files detailed below are text files created by the post processing UNIX scripts containing information required by the secondary system in order to archive data files that have been transferred from the primary system.

Setting up an experiment at version 4.0

The UMUI post-processing screen allows archiving to be switched on or off. This sets a variable in the SCRIPT file. Next, the stream option must be set. Five stream options are now available which allow certain stream combinations for archiving. One of the following options must be chosen:

1. All streams separately.
2. All streams together.
3. Dump and boundary files together, others separately.
4. PP and mean PP files together, others separately.
5. Dump and boundary files together, PP and mean PP files together.

The next screen reflects the chosen stream option, in that if the user specifies all streams to be archived together, the next screen will ask for the number of archive requests per job for a mixed trigger file only.

Users specify the retention period of files by specifying one of the following options:

1. Expiry date (YYYYJJJ) where YYYY is the year and JJJ the julian day.
2. Retention period in days.

If an invalid expiry date is coded then the archive server system must set a default. Upon completion of these screens, the process job will set variables required to convert such requests into information required by the archive system. Such variables are to be found in the experiment PPCNTL file.

Trigger file names and format

Example Trigger file name:

```
HCEAFU.CBWSK.V304DMP.D94335.T102759
   ^       ^       ^          ^
prefix  runid   version  year, julian day
                & type   and time of creation
```

Prefix:

- HCEAFU - Unprocessed trigger file

Possible values for the stream type are:

- DMP - Dump
- MPP - Mean pp
- PMP - Mean pp and instantaneous (daily) pp
- PP - instantaneous (daily) pp
- BF - boundary
- DB - dump and boundary
- MIX - all stream types together

Example of trigger file contents:

```
CRC.CP.CBWSKA.DAJ1630 94355 36 rf990 t20lw
CRC.CP.CBWSKA.DAJ1650 94355 36 rf990 t20lw
CRC.CP.CBWSKA.DAJ1670 94355 36 rf990 t20lw
```

For a new run TF the first line will be *'#new#'*. For the first TF for a continuation run the first line will be *'#continuation# filename'*. The filename is the last file archived for that stream as recorded in the $DATAW/$RUNID.pphist file. Otherwise the first line is blank.

The Trigger File contains the following information for each file. The last three are Met. Office specific items.

- The file name for the secondary system.
- The julian date of expiry.
- The tape type (at present 36 track).
- The TIC code for your group.
- The User ID.

Action to be taken on archiving failures

a) If the model has stopped cleanly

The 'autopp_tidyup' script has been written to tidy up archiving after a system or archive server failure for the previous run. The script carries out the following operations:

- Search user's experiment directory for current runid trigger files.
- Transfer remaining trigger files on primary system in *$DATAM* to secondary system in order to archive data files on disk from a previous crashed run.
- Input contents of .failure file (archive requests from failed run) into qsserver in order to process unarchived data files.

b) If the model has crashed

- If the run has crashed, check the trigger file contents on primary system with associated transferred files on the secondary system. In exceptional circumstances it is possible that the run could crash after a data file transfer but before the data file name has been appended to the relevant trigger file. In this case, update the trigger file with the missing entry.
- If there are data files remaining on the primary system that should have been archived, then construct a $RUNID.failure file under *$DATAM*, using the format in the example below, starting each line in the first column. Each archive request is followed by a delete request that removes the now transferred file from *$DATAM*. Daily dumps that are not archived should just have a delete request if they are no longer needed, BUT
  - Do not delete the last safe re-start dump.
  - Do not include a delete request for the latest dump on-line, even though this may need to be archived. A delete request for these dumps will be sent by the model when the next dump of this type is created.

  Example: file *cbwsl.failure*

```
** WAKEUP **
%%% cbwsla.daj16d0 ARCHIVE DUMP
%%% cbwsla.daj16d0 DELETE
%%% cbwsla.p1j16d0 ARCHIVE PPNOCHART
%%% cbwsla.p1j16d0 DELETE
```

c) Checks before re-submitting run

- If any old trigger files from a previous run with the same $RUNID, rather than the one that has just failed, are residing in your *$DATAM* directory, then they will be copied to the secondary system; they must be DELETED.
- Trigger Files from the current run will have associated secondary system files on disk waiting to be archived. A run may have to be restarted at the last safe restart dump (the beginning of the last period I mean) if there is a system crash. Therefore files from the crashed run which have a model date later than the restart dump date and are on the secondary system waiting to be archived should be either deleted or the relevant trigger files have such entries removed. These files will be re-generated. (This may not be necessary on systems which allow files to be replaced or allow multiple copies of the same file.)

- Check that your $RUNID.pphist file contains the correct 'last file archived' (*_LAST_FILE) per archive stream type. This file should be on the secondary system but may not have been archived to tape if it appears in a trigger file still on the primary system. In the latter case it should be the last file in the trigger file. (This file is used by the archiving system to identify the tape that is in use for that stream at the Met. Office).
- Finally, do not copy backup versions of Trigger Files in your *$DATAM* directory, as the scripts perform a 'grep' command to find all files containing the pattern 'HCEAF'. If these files also have the correct jobid letter for the current run the files are copied to the secondary system and deleted.

3.19 Modifying UM Source Code

Author: Rick Rawlins, Last Updated: 15 Apr 96

3.19.1 How is the source code stored?

Source code is held in an nupdate program library, where nupdate originated as a Cray proprietary package - "update", later upgraded to "nupdate" - used for source code management, which now has public domain status. A program library consists of a number of DECKs, each DECK normally containing a single subroutine, with every line of code labelled - for new DECKs this is by DECK name followed by consecutive line numbers. Subsequent releases of the Unified Model incorporate permanent changes which are labelled by the name of individual modification sets.

In addition there are nupdate *DEF directives embedded within DECKs which define names to act as conditional switches for excluding or including sections of code. nupdate allows source code to evolve in a structured fashion, where temporary changes can be tested and developed privately before optionally forming permanent upgrades.

Formal change control mechanisms for source code are described in UMDP 2: Change Control Management of the UM System[2]. The Unified Model is organised into releases of the model and versions of individual sections of the code. This structure, described in section 3.11 (Science Options), needs to be well understood by any user wishing to make temporary or permanent changes to the code.

3.19.2 Viewing source code

The master copy of each UM version $VN (= 4.0, 4.1, etc) is held on the Met. Office Cray C90 at $UMDIR/vn$VN/source/umpl for fortran/C code and at $UMDIR/vn$VN/source/umsl for unix script code. These program libraries cannot be viewed directly on the Cray and require extraction through Cray nupdate. This task is performed centrally for Met. Office users and listings can be browsed via the source code listing page of the UM Documentation page of the Met. Office Web. On systems other than a Cray portable model users can inspect source code directly within the $UMDIR/vn$VN/source/umpl or umsl directories.

3.19.3 Making a change

A simple example of a modification set, or "modset", is given below which replaces lines labelled ATMSTEP1.77 to ATMSTEP1.79 in DECK ATMSTEP1 by a new line and introduces a new line after ATMSTEP1.96:

```
*ID ARRZF401                        */ identifier name
*/ Include test write statements comments for mod set
*DECLARE ATMSTEP1                   */ declare DECK to be modified
*D ATMSTEP1.77,ATMSTEP1.79          */ delete between these 2 lines inclusive
      WRITE(6,*) 'TEST',A_STEP      */ replace by new line(s)
*I ATMSTEP1.96                      */ insert after this line
      WRITE(6,*) 'REACHED HERE'
```

which can be held in a personal file. This file can contain one or more modsets and must be located on the target machine for running the model.

To include this modset in your model run go into the UMUI and select window **atmos_Compile_Mods**
`Atmosphere`
`-> Compilation and modifications`
`--> Atmos and control user modifications`
and enter the file name(s) containing the modification set. Execution of the atmosphere model will include your change as a temporary modification of the source code, compiled and linked to create a new executable file.

The UMUI generates files MODS_ATM and MODS_C in the job library to hold atmosphere/control fortran and control C language modification filenames respectively. During execution of the model SCRIPT, modsets are extracted if compilation is requested and concatenated into internal run-time files defined by environment variables UPDATE and UPDATEC.

Similarly MODS_OCN and MODS_SCRIPT hold ocean and script mods, and use environment variables UPDATEO and UPDATES respectively. Fortran and C mods for the reconfiguration program are held in files called MODS_RECF and MODS_RECC. The different types of mods are each specified in the equivalent UMUI panels to the "Atmos and control user modifications" panel referred to above. At present all general control Fortran and C model modifications have to be specified within the Atmosphere section, even for ocean models but the relevant panels are accessible from within the ocean part of the UMUI. At future releases the various internal models will become more independent from the control code.

3.19.4 Viewing changed DECKs

The updated DECKs (eg ATMSTEP1, ATMDYN1) resulting from a modification set "mymodset" can be listed with the new sequence numbers (using Cray nupdate only) by:

```
VN=4.0                                  #  Version 4.0
PL=$UMDIR/vn$VN/source/umpl             #  UM program library
DECKS="ATMSTEP1 ATMDYN1"                #  Changed decks
nupdate -p $PL -i mymodset -q $DECKS -o "ed,in,um,sq" \
        -s newdecks
cat newdecks                            #  List changed decks
```

With portable nupdate it is only possible to view the modified deck without sequence numbers. This can be done by using the following nupdate command (which will also work on the Cray) instead of the one above:

```
nupdate -p $PL -i mymodset -q $DECKS -D
```

This will create individual files with the same name as the decks that have been modified.

To view code as it is actually executed it also needs to be processed with the correct DEFS set to include only relevant code. The example below, which contains some unix script DEFS, shows how to use the -d option in the nupdate command to do this:

```
DEFS="METOCRAY CRAYPVP"
nupdate -p $PL -i mymodset -q $DECKS -D -d $DEFS
```

The $DEFS environment variable will need to contain suitable switches for Fortran/C or script code (see section on compile switches below).

3.19.5 More about nupdate

Two versions of nupdate exist, (1) Cray nupdate and (2) portable nupdate:

- Cray nupdate is supplied with current releases 7.0 and 8.0 of the Cray UNICOS operating system but it will not be supported at UNICOS 9.0. It has the full functionality shown by the man pages for the Cray but has not been made available by them on any other platform. The source code released into the public domain is mostly in fortran, with some C routines, and has been made to work on a SUN SPARC workstation under Solaris 2.1, but porting to an HP 9000 with HP-UX 9.05 or a DEC ALPHA running OSF/1 has not yet been achieved.
- Portable nupdate has been written in C for the portable model and is described in UMDP X2: Nupdate Source Code Manager [30] which also includes details of nupdate commands. Portable nupdate operates on a native format program library that can be browsed directly. When the source code originates from Cray binary format libraries, as is the case for the UM where the master copy is held on the Cray C90, it is necessary first to convert to the native format. The main lack of functionality currently lies in its inability to reproduce nupdate source code used to make program libraries (including supporting the -s option).

Nupdate features used in UM source code:

- Compile switches. The UMUI sets up a list of *DEF switches for fortran/C code in the UPDEFS file of the job library to select different portions of code at compile-time. Blocks of code within routines are then only made available to the relevant model configuration. An example is given by the use of *IF DEF,ATMOS;*ENDIF line pairs to isolate atmosphere-specific model code. In addition each DECK of code is protected by a *DEF switch which indicates which section the DECK resides in, allowing a choice of alternative science options to be provided by the system.

  For script code the only *DEFs required are those in the SCRDEFS environment variable in the set-globalvars script, which is set up as part of the build process when the UM is installed on a system.
- Insertion of common code. The *CALL facility allows a common section of code (a COMDECK, typically the declaration and definition of a constant or group of control variables), to be inserted globally throughout the program. Nupdate features several sweeps through the source code, so that a modification to a COMDECK is carried through to each DECK containing the COMDECK call and a full set of DECKs is extracted which reflect the total change.

Nupdate processes modifications sequentially and keeps a record of previous modsets going into successive UM releases so that earlier states of the program library can be retraced.

It is recommended that nupdate output options in UMUI panels are set to in,ed,um (except with portable nupdate which does not have these options). This sends to standard output an echo of your modification set, a summary of the changed lines and a list of any modifications that remain unprocessed.

Nupdate can be invoked in several modes: full, normal or quick. Full updates are used to generate new source code libraries at build time for a new version. Normal updating is used in the extraction step preceeding compilation for individual jobs to ensure that changes in COMDECKs are propagated. The quick mode allows specific DECKs to be modified but demands that a *COMPILE directive is supplied for each DECK, which places the onus on the user and is therefore not employed in the system.

3.19.6 Setting up modification sets

A practical method of obtaining a modification set when more than a few lines of code are involved is to edit a copy of a DECK directly. The Cray utility nmodex can then be applied to form a difference of library and edited DECKs as follows:

```
cat > listdecks <<EOF            # list of decks to be changed eg. ATMSTEP1
*C ATMSTEP1
EOF
VN=4.0                           # Version 4.0
PL=$UMDIR/vn$VN/source/umpl      # UM program library (umpl/umsl)
EDITDECKS=editdecks              # file which will contain edited decks
nupdate -p $PL -s $EDITDECKS -i listdecks       # extract source without
                                                # sequence numbers
[ edit decks in file editdecks ]
nupdate -p $PL -s temp.s -o sq -i listdecks     # extract source with
                                                # sequence numbers
nmodex -e $EDITDECKS -s temp.s -h \
            -i GUUZF401 -m new.modset           # get difference
```

creates a new modification set 'new.modset' from an edited copy 'editdecks' referred against the program library. [Note, Cray nmodex creates a lengthy header which should normally be deleted by the modset author to prevent contention with other conventions for labelling modsets (DC= and duplicate *ID can cause problems).]

There is a portable version of nmodex with limited functionality that has been adapted to provide a simple application for generating modsets for Met. Office users on HP workstations and for users of the portable model. To use portable nmodex with portable nupdate you need to do the following replacing deckname with the name of the deck you are working on:

```
VN=4.0                                          # Version 4.0
PL=$UMDIR/vn$VN/source/umpl                     # UM program library (umpl/umsl)
cp $PL/deckname.dk ./deckname.tmp               # create temporary copy of deck
cut -c 1-72 < deckname.tmp > deckname.ed        # remove line sequence numbers
                                                # use 1-80 on Met. Office HPs
                                                # only (see note below **)
rm deckname.tmp                                 # remove temporary copy
[ edit deck in file deckname.ed ]
cp $PL/deckname.dk ./deckname.src               # Get copy of deck with
                                                # sequence numbers
nmodex -e deckname.ed -s deckname.src \
       -i GUUZF401 -h -m new.modset             # get difference
```

This will create a modset with id GUUZF401 in file newmodset. This can be included in a run by adding it in the relevant panel of the UMUI.

You should not:

- Use tab characters - these may give different spacing when ported to different machines;
- Continue into column 73. (** Note however that the scripts library has been created with a width of 80 characters, but if a modification is done to a script deck with portable nupdate, which is restricted to 72 characters, all lines in the deck concerned will be truncated to 72 characters. However this problem does not apply to the portable release of vn4.0 where all script lines are less than 73 characters.)

(see UMDP 3: Software standards for the UM: Fortran and Unix [3]).

Naturally, if the correction modset is very minor, it may be simpler to key in the nupdate lines directly - this may well be quicker for modsets of only a few lines. Note that it is preferable to keep the order of changed nupdate line commands the same as the order of the source in the DECK. Although nupdate will cope with processing a DECK in a non-consecutive manner, the resulting modset identifier numbers for new included code will not be monotonic increasing through the DECK, which can be confusing when inspecting the updated source.

3.19.7 Conventions for naming decks and comdecks

It is useful to have a convention for naming decks and comdecks so that automatic software tools can process decks in an ordered manner, such as the method by which source code is extracted for browsing using html links on the workstation strings. All deck and comdeck names are currently limited to 8 characters in total. It is usual, though not mandatory, to have one deck per subroutine - an exception is allowed when a number of small and closely linked routines can be held together. The name should be similar to the underlying subroutine name, subject to the limitation of characters, and need not be simply the first 6-7 letters of that name. The aim is to be able to infer the deck name, although search facilities may be needed for programmers unfamiliar with the source code.

Control decks, ie those top level decks requiring compilation each time that the model is compiled, with no pre-existing object code, end in 1, eg ATMSTEP1. [This allows some scope for future expansion for cases of alternative control code to be handled by the system, but there are no current plans to achieve this.] It is often the case that control routines have a number of potential combinations of interior *DEFs that makes pre-compilation impractical. Other decks lie at a lower level within pre-compiled sections, with alternative schemes specified by a version no. and release version, eg SWMAST1A. Completely new decks will require a new release, eg SWMAST1B, but note that later releases may be handled internally by the addition of code within *DEF switches, and new decks may not need to be introduced. Comdeck names should start with C and end in an alphabetic not numeric character.

If several modifications are made to a particular *DECK within a single *IDENT it is preferable to order the changes in the sequential order of the *DECK. This is achieved automatically by nmodex, and is standard practice for most users. Nupdate will append the *IDENT.xxx label for each changed line in the order that those changes appear in the *IDENT, so if these are not in start to end order, the labels of the id will also not increment regularly from start to end. This makes it more difficult to view what changes have taken place, and nupdate can have trouble interpreting commands such as *D MYIDENT.9,2 although this may seem to be valid when line MYIDENT.9 precedes MYIDENT.2.

Diagnostic messages from the nupdate step for the latest model build are available to Met. Office users via the UM Documentation page on the Met. Office Web.

3.19.8 Pitfalls

The main problem occurs when more than one modification set is applied and overlapping changes may occur. If an attempt is made to change a previously deleted line then nupdate will fail. If multiple modifications are targeted for the same location, nupdate will continue, but with warning messages. Error messages do not always point to the problem DECK but may indicate the next DECK to be processed.

Non-ascending sequential *ID labels can cause difficulties for nupdate to interpret. Avoid commands such as *D MYIDENT.9,2, even if they should appear to be valid, as when line MYIDENT.9 precedes MYIDENT.2.

A default output option for the application of Cray nupdate enabled for Met. Office users is -o dc, which requires that each modset needs to include a *DECLARE statement for the DECK being modified - otherwise nupdate will fail. This is a useful discipline to ensure that modifications are passed through to the program. If this option is disabled, explicit *C statements are required for each DECK to be extracted for the compile step. If a statement is omitted it is possible for a program to complete successfully, seemingly include the correct modifications but not produce the desired result.

Beware that code modifications may not be included in your compiled executable file. In particular, you may change code in a version of a science routine that has not been selected through the UMUI when defining the model job. For example a modification may be created to alter subroutine SWMAST in deck SWMAST1A but this will have no effect on a job where version 2A of the SW radiation has been chosen, since the effective code selected for compilation lies in deck SWMAST2A. This may not be immediately obvious from inspection of the output, which will show that nupdate has correctly modified deck SWMAST1A, but no substitution of compile file contents will take place. Conditional *DEF statements at the head of each deck describe the scope for different versions of sections, and a list of decks comprising each section version for 4.0 is held in an obj_xref file within the $UMDIR/vn$VN/source directory. More discussion on versions, releases and sections of science code can be found in 3.11 (Science Options).

3.20 File Utilities

Author: D.M. Goddard, Last Updated: 14 Feb 96

The utilities are a collection of standalone executables. Most are located both on the Cray and on workstations. They require small amounts of memory and can be used interactively.

The majority are run by scripts located in directory $UMDIR/vnn.m/scripts where n.m is the UM version number, eg. '4.0'. The environment variable UMDIR is automatically initialised at logon time. *bigend* is only found in $UMDIR/bin on the workstations. Before you use the utilities the environment variable UMVERSION must be initialised and exported. The best way of doing this is to add the following lines to your .profile.

```
UMVERSION=n.m
export UMVERSION
```

The syntax for all the utilities is given in UMDP F5 (see [24]).

Unified Model data files are binary files in a format described in UMDP F3 (see [23]). They include model dumps, fieldsfiles (.pp files output by the UM), ancillary files, boundary datasets and observation files.

Most of these utilities will manipulate files created by earlier versions of the model. Any exceptions are stated explicitly in UMDP F5.

Table 3.1 lists the utilities which are available.

Utility	Platform	Description
cumf	Cray/ws	Compares two UM files. Usefui in testing for bit comparison or highlighting differences between dumps
pumf	Cray/ws	Prints out contents of a UM file. Useful for checking headers.
ieee	Cray	Converts Cray UM file into IEEE format. Necessary conversion for transferring dumps from the cray to a workstation.
convpp	Cray/ws	Converts fieldsfile into sequential PP-file for PP processing. Allows users to display dump data on workstations using PP based software.
mergeum	Cray/ws	Appends a UM file onto another at a place specified by the user Useful for combining two boundary data for use in long runs of the model.
bigend	ws	Reverses the order of bytes in each word of a UM file. Needed for DEC Alpha workstations.

Table 3.1: File Utilities

3.21 Troubleshooting

Author: Rick Rawlins, Last Updated: 14 Feb 96

3.21.1 So you have problems with running the model?

The UM is a large and complex system with many opportunities for mistakes to occur and errors can become apparent at a number of stages. The logical sequence of a successful run of the model starts with the experiment being defined through accessing the user interface. Once experiment files have been created, a job is launched on the target machine and UM program scripts are initiated. The standard pattern of execution is first to invoke the reconfiguration program, then compile the model to generate a new executable file and finally run the model. For any particular run, each execution stage is optional. Of course, these stages may all complete successfully but the model integration may still contain serious errors, as evident by an inspection of model output fields.

For Met. Office users, errors within the UM system for successive versions are described in the IBM dataset 'UM1.PROBLEMS.TEXT', with a browsable copy on the UM documentation page: Problems library. It is encouraged that the dataset is updated as system errors and solutions are discovered and all Met. Office users should look here first when they come across a new problem. A portable system for workstations is under development.

A number of topics are covered in the following sections which may give clues to the source of the problem. Where comments predominantly refer to findings with the Cray C90 as target machine to run the model, then this is indicated by the section title. Considering problems in the different stages separately:

Problems during set-up in the UMUI

There is a significant level of verification of users' entries within the UMUI. Each variable within a window has explicit ranges that are checked against, and the validity of the user's responses is checked each time a window is exited. A facility is available to pass through the entire set of variables for the model, providing cross-checking of consistency between the entries of different sections. In addition there are similar tools to inspect the list of STASH output diagnostic requests and profiles for consistency. Most inappropriate settings of UMUI entries will be captured by this method. The last line of defence comprises any error messages that may be revealed when the job is processed to generate its library of files for the target machine. Although the UMUI can be relied on to create the correct file content in nearly all cases, there may be occasions when a rare combination of options is processed, that wrong values are generated - which should be borne in mind for error investigations.

The most common errors for users, having copied a working experiment are:

- Not changing user identifier for the target machine - select window **personal_gen**
  `Personal details`
  `-> General details`
- Picking up environment variables defined personally from the previous job, eg USERR=$HOME/myancil may be valid for the previous user but not for you. Environment variables are set in window **subindep_FileDir**
  `Sub-Model independent`
  `-> File and Directory Naming`
- Not creating the DATAW or DATAM directories in which the model generates files, eg DATAW=$HOME/$EXPTID automatically defines the name of a suitable directory, but this must first be created on the target machine. If this has been omitted the model will fail at an early stage attempting to create the first file, ie $RUNID.out for DATAW, in the non-existent directory.

- For new users, not creating the directory $HOME/umui_runs to hold job files created by the UMUI and passed to the target machine.

Output listings from a model run

A standard experiment compilation and run can easily produce 10k lines of printout, and it is useful to have some idea of the overall structure of the information and know what to search for.

A listing will consist of:

- Unix output list. Sdout (standard output stream) from the job SCRIPT file is listed until script qsmaster is reached, which calls the underlying scripts: qsprelim, qsmain and qsfinal, and gives explicit messages for starting and ending. [qsprelim includes the reconfiguration step; qsmain compiles and runs the model; qsfinal deals with the history file from the model.]
- Fortran/C output list. Output from each of the above scripts is concatenated into a file labelled with a banner "OUTPUT".
- Unix housekeeping. Lists of files within the specified UM directories on the target machine, plus some accounting information.

Sdout and sderr output streams from scripts are intermingled so that if an error occurs that initiates a unix message, say a traceback in qsmain, this will place the unix message after the "Starting script : qsmain" line. However there may well be error messages generated from the Fortran code and these will be located in the "OUTPUT" file - in the case of a failure, at the end of the file. Return codes are checked from each script - and for lower level scripts - in the case of an error there will be a message in the unix output. The "OUTPUT" file contains in order:

- Echos of all job files input to model. Optional but should always be included so that model set-up information is retained.
- Output from the reconfiguration starts after the character string "qsprelim: %recona% Atmosphere reconfiguration step" for the atmosphere and "qsprelim: %recono% Ocean reconfiguration step" for the ocean models. After the first "FIXED LENGTH HEADER", the header and contents of the input dump are listed - followed by the new land sea mask, if reconfigured. Subsequent occurrences give contents of the newly reconfigured dump, followed by details of ancillary files introduced into the dump. Timing information for the reconfiguration follows if the TIMER has been enabled, after "FLOW TRACE SUMMARY".
- Information from the nupdate step to extract changes in source code following "qsmain: %UPDATE%".
- Fortran and C compiler messages after "qsmncompile:".
- Model output at run-time following "qsmain: %MODEL%:" set-up information from STASH processing routines come first, with a "LIST OF USER_DEFINED DIAGNOSTICS" giving a summary of individual diagnostic requests. The next critical stage to reach is "READING UNIFIED MODEL DUMP" which gives details of the input starting dump. Initialisation is completed when "ATMOS TIMESTEP" is reached (for the atmosphere model). Timing information for the model follows if the TIMER has been enabled, after "FLOW TRACE SUMMARY".
- Information from the history file recording the progress of the run follows "HISTORY FILE PRINTOUT".

Problems during model initialisation: reconfiguration and compilation

A script to reconfigure the initial model dump is executed first and will be the first contact with real data, and will fail if initial dump or ancillary files are absent. This will be revealed by generic error messages from the I/O routines "FATAL ERROR WHEN READING/WRITING MODEL DUMP".

Note that this message could refer to any dump format file, which includes ancillary and boundary files. Note also that the I/O routines will not necessarily point to an error when file opening is first attempted: a "**WARNING: FILE NOT FOUND" message is produced if the file does not exist. There will often be a number of such messages in a standard valid reconfiguration, since all potential ancillary files are opened and the logic to decide which ancillary files are needed is only introduced at a later stage, before explicitly reading the files.

Model scripts initiate an nupdate step that introduces user changes in source code from the basic release (see section 3.19: Modifying source code). Conflict can occur between competing changes - these are signalled by explicit nupdate messages. The model can fail to compile - again explicit messages point to the offending subroutine in the "OUTPUT" listing. There may be additional earlier messages in the unix output listing arising from Cray C90 pre-processor errors, triggered before the compilation step. The unix output listing provides a check that the correct set of modification files have been copied into the program.

Failures during model execution

Can arise (most likely first) from:

1. User errors in model set-up.
   - Incorrect filenames specified;
   - Inappropriate parameter values chosen;
   - Logic errors in user updates.
2. UM system errors in control.
3. Science formulation errors.
4. Input data errors.
5. Computer operating system/hardware problems.

Methods are described for investigating failures during model execution (see section 3.21.2) and discovering sources of error.

Errors in results only apparent after successful completion of the job

This is the trickiest problem! Cause(s) could lie in one of many areas and may require much detective work to resolve. Later sections gives hints on some tools that may help attacking the problem, using run-time diagnostics (see section 3.21.3). Inspection and comparison of model dumps, boundary and ancillary files, and output pp files, can be achieved by the use of UM utilities such as pumf and cumf, described in section 3.20 (File Utilities).

3.21.2 Investigating failures during model execution

If an internal model check perceives that a gross error has occurred, an integer error code indicator is set and the model exits via a 'soft failure' in which control is passed back to the top level control routines in an ordered way. A partial error message is passed to the unix level giving the name of the routine in which the error was trapped and an explanatory comment. A fuller error message is written to the Fortran listing, and this can point immediately to the problem or offer no guidance or be downright obtuse! Bear in mind that the model is relatively robust to field values extending outside their normal range and that it may require some iterations of extreme values before an error is detected, such as by a negative absolute temperature being calculated. Also the error may be flagged in a routine some distance away in the calling tree from where the error originated. The atmosphere model will generally fail in routines LSP_FORM or SWRAD when meteorological prognostic fields become contaminated with wild values, leading to catastrophic growth of instabilities.

What to look at first

Obviously the output to see where the error occurred. The output should be scanned from the top to see what system messages are generated. On the Cray C90: a "floating point exception" indicates that an attempt has been made to use an illegal value in a floating point operation, usually because an element of an expression has not been initialised. ie this requires illegal values of A or B in:

```
C=A*B          ! can generate floating point exception
C=A            ! but a simple assign will not: no fail
```

On the Cray C90: "ARLIB Maths library error", or similar, is invoked when an illegal value is input to a maths library routine such as LOG or SQRT. On the Cray C90: "Failed %ALLOC..." is a system message stating that too much memory was required. Valid increases in memory may arise from a change of science routine, or extra output diagnostics, or increased model field sizes, of course. However dynamic allocation of local arrays may pick up a corrupted dimension length, perhaps through incorrect initialisation or, more seriously, through overwriting of the address contents by an earlier error. For the atmosphere model it is possible to juggle performance and memory by changing the number of segments for physics calculations.

[On the Cray C90 a traceback using the debug utility is automatically invoked by UM scripts after a model failure; other platforms need this to be done manually. Searching for A_STEP will show which timestep the atmosphere model failed on. If this points to a failure in the first timestep it is almost certain that there is a major error in set-up.]

The next place to look is from the bottom of the listing backwards, to determine how far the integration reached and where the error was trapped if a soft failure occurred. Note that in perverse cases with some hard failures the last buffer written to the output stream may be lost and the error point could be further on than indicated.

Further investigations (for Cray C90 users)

Tracebacks are only provided for routines compiled with the debug option z enabled under cft77; ie generally only for control code and updated code excluding pre-compiled sections. Hence a temporary nupdate modification containing a *COMPILE of the failing routine and calling sequence is needed to obtain more information of local values at failure time. Note also that the traceback is unreliable if running multi-tasked and the Cray C90 pre-processor FMP needs to be switched off . Compiler options for the atmosphere model are set in window **atmos_Compile_CompOpts**

```
Atmosphere
-> Compilation and modifications
--> Atmos and control. Compiler options
```

Enabling option i under cft77 sets unintialised variables to an indefinite number for every call to the routine. This provides a useful check since it forces a run-time error when an uninitialised local variable is used in a floating point operation or array subscript, although dummy arguments and common block variables are not covered. A complementary test is provided by the segldr -f indef option invoked under the SEGLDROPT environment variable in the UM script (or by explicitly setting PRESET=indef in the segldrfile). This presets variables in static storage to an indefinite value at the start of the job. Hence if initialisation by the user is incomplete this will create a floating point exception when used in an operation.

The run-time check -R under cft77 can also give useful information. -Rbc produces messages if array bounds are exceeded within a routine. -Rabc additionally compares the number and type of arguments passed between calling and called routines. However note that the UM produces a large number of messages pointing to inconsistencies between real and integer arguments across a routine call - these are due to the widespread practice of invoking extra arguments to access elements of mixed type arrays such as in lookup tables or the main D1 data array.

Problems still unresolved?

There is usually no alternative but to include an increasing number of write statements within the code to try to home in on the error. You may prefer to use a more fancy debug utility but these tend to need familiarisation and the size of the UM code can overwhelm some applications. Overwriting problems can be very difficult to track down. One useful technique is to include a write statement and/or calculations within routine TIMER, since this is called repeatedly throughout the control code and can sometimes identify when a problem begins. Otherwise go back to a model run that worked before you made your changes and gradually isolate components that are associated with the failure. The file comparison utility cumf may be useful in this exercise, see section 3.20.

Note that multi-tasked operational forecasts are not bit reproducible and it may be necessary to repeat model runs until a specific set of conditions re-occurs. It is preferable to investigate a problem run that is repeatible and it is worth trying to run in a reproducible fashion, ie multi-tasked with no assimilation plus *DEF REPROD or single tasked.

3.21.3 Run-time diagnostics

Point prints of meteorological fields

Atmosphere model only. It is possible to obtain simple printed output of the primary meteorological variables for specified timestep intervals and located at a specific grid location, with neighbouring values also being optionally included. Maxima and minima of fields for each level of the model may also be obtained and is a useful monitoring facility. These are set up through windows **atmos_Control_Output_Writes_Patch** and **atmos_Control_Output_Writes_MaxMin**

```
Atmosphere
-> Control
--> Diagnostic (Point) writing
---> Patch writes AND Max-min prints
```

and can be switched on without re-compilation. More experienced users can insert code based on this method to obtain point prints after various stages of execution of the model timestep.

Timestep increments

Atmosphere model only. Selection of the UMUI window **atmos_Control_Output_Writes_Incr**

```
Atmosphere
-> Control
--> Diagnostic (Point) writing
---> Increment writes
```

allows the user to request a printout of statistics of field increments between a specified number of timesteps. This is useful for identifying the onset and location of the growth of instabilities. It adds significantly to the cost of execution and so should only be used in investigative mode.

Bit comparison of dumps

Testing for exact bit comparison between model dumps generated with and without a modification is a very stringent check on system only changes. An option is provided to write out to disk the main data array D1 within the model at various stages through the model timestep, making it easier to discover if and when a loss of comparability was introduced. Select window **atmos_Control_Output_Writes_D1**

```
Atmosphere
-> Control
--> Diagnostic (Point) writing
---> Dumps from WRITD1
```

but beware that a large amount of data may be written out to files. The same facility is available in the ocean model from window **ocean_Control_Output_Writes_D1** In addition this technique can be adopted by programmers introducing code to intercept any array within the model.

3.21.4 Performance diagnostics (for Cray C90 users)

TIMER

A UM timing routine (TIMER) records how much cpu and elapsed time is spent in major model routines, controlled by software calls at the control level. Timings are given for the sum of calculations for called routines at a lower level and so the output refers to the cost of sections of code rather than individual routines. For Cray C90 users, TIMER returns the correct values for multi-tasked code as well as single tasked code, although the speedup value over a single processor will not be appropriate unless the model has stand-alone status on the machine.

Perftrace

Perftrace measures the efficiency of use of Cray C90 hardware by and can split the information down to individual routines. This option requires a re-compilation of the model, but for Met. Office users each section of UM code is compiled with the relevant switches when a new version is built to provide the alternative object code. This is available for one or more atmosphere model science routines via the UMUI windows accessed from

```
Atmosphere
-> Scientific Parameters and Sections
--> Section by section choices
```

or for all routines via window **subindep_Compile**

```
Atmosphere
-> Compilation and modifications
--> Sub-Model independent Compile options for the model
```

Output from perftrace can be viewed with the perfview utility and gives information mainly for single-tasked code, giving details of timings, vector performance and in-lining.

Atexpert

A Cray utility for analysing multi-tasking performance, requiring re-compilation with extra switches enabled. The UM scripts have extra logic to expedite this, but require a hand-edit of the SCRIPT file. The main application for the utility is for display in an X-windows environment, and allocated Cray C90 resources may not be sufficient to make full use of this.

Other tools

Implementation of other utilities require user action to modify UM scripts. The most useful of these is probably procstat, which gives information on memory use, particularly with respect to I/O operations. Procstat does not require re-compilation and its dedicated output can be viewed using the procview utility.

Other utilities are available, but have less application for the UM:

- hpm: hardware performance monitor;
- prof: cpu use profile.

3.21.5 Test diagnostics

Atmosphere model only. A set of analytic fields can be calculated and produced as standard output through the STASH pp system. The diagnostic names and analytic formulae used for generated the fields are described in UMDP D7: Test diagnostics for output [22]. These special fields can be generated as individual diagnostics through STASH output panels of the user interface in the standard way. Alternatively, a macro has been set up to create a standard set of the test diagnostics and this can be initiated by accessing the window **atmos_STASH_Macros_Test**

```
Atmosphere
-> Control
--> STASH macros
---> Test diagnostic macro
```

Analytic diagnostics are useful when a system is being set up that requires a number of transfer or intermediate stages between UM runs and the final display of output.

3.21.6 Testing new changes and problem solving

For any change or investigation of a problem that affects the UM system it can be an advantage to perform some of the tests at low resolution, such as in the climate 48*37 model configuration. This can be used as a test-bed for rapid turnaround while bugs are explored and fixed before trying out the full solution at a higher resolution.

Appendix A

The Portable UM

Author: Nicola Farnon, Last Updated: 14 Mar 96

A.1 Introduction

The Unified Model has taken many years of effort to develop into its current state-of-the-art meteorological model. Because computer hardware is being improved at a rapid rate, it is important that we are able to move our code from one system to another with minimal code change in order to maintain our high-level status. It also means that other research establishments may use the UM for research and development.

A.2 History

The first available release of the portable Unified Model was vn3.2. It was based on a given set of fixed experiments which had been previously set up on the UKMO IBM mainframe User Interface. Vn4.0 of the Unified Model will be the first release that includes the X-Windows based Unified Model User Interface, this will give external users the flexibility to change the set up of their own experiments.

A.3 Differences across platforms

The main criteria of the portable model is for the Fortran and C code to remain the same as that of the Unified Model. In other words, the Portable Unified Model *is* the Unified Model.

There are some aspects, however that do make them differ. These are:

1. The Operating system.
2. Which source code management tool are you using, Portable, or Cray Nupdate?
3. Can the Fortran compiler handle dynamically allocated arrays, or is the UKMO routine lexcon required to do so.
4. What the Fortran / C interface is?
5. Which C variable type has the same wordlength as the default FORTRAN REAL on this system?
6. What data format your system can handle: IEEE 32, or 64 bit, or Cray 32, or 64 bit? Sometimes the IEEE formatted data requires to be bigendian'ed.
7. What Fast Fourier Transforms are used.

Appendix B

The UK Met. Office UM

This section contains information which is only relevant to users at the Met. Office. This information will not be of interest to external users.

B.1 File Transfer

Author: D.M. Goddard/Stephen Lorrimer, Last Updated: 13 Mar 96

B.1.1 Introduction

There are several routes for transferring UM data from the Cray C90 to other machines in the UKMO. Transfers are available to workstations both directly and via COSMOS. The method of transfer depends on the type of file to be transferred. Section B.1.2 describes how to transfer UM dump files and section B.1.3 how to transfer model output stored as fieldsfiles.

B.1.2 How to Transfer UM Dumps

These procedures are described in UMDP F5 [24]

Transfers from the Cray C90 to COSMOS

- Set up environment variables

```
$ UMVERSION=vn4.0
$ VN=4.0
$ export UMVERSION VN
```

- Convert UM dump from 64-bit cray numbers to 32-bit IEEE numbers

```
$ /u/um1/vn4.0/scripts/ieee -32 dump.file dump.ieee
```

- Send IEEE file to COSMOS. *Note: quotes are important.*

```
$ /u/um1/vn4.0/scripts/cray2hds dump.ieee 'cosmos_filename'
```

Transfers from COSMOS to Workstations

On a *DECNET* server workstation:

- Copy IEEE file from COSMOS to workstation.

```
$ hds2hp cosmos_filename dump.file
```

- If output is required in PP format run *convpp* see section 3.20 for details.

In NWP, the DECNET server workstations are fr0500, fr0800 and fr1300.

File transfers from the Cray C90 to workstations (Direct)

If the dump is not required on COSMOS the user may transfer the IEEE file directly to the workstation using *ftp* in binary mode. To initiate transfer from Cray C90:

- Open link to file-server workstation (in this case fr0600).

```
$ ftp fr0600
```

- Input user name on workstation at prompt if different to user name on Cray C90.

```
Name (fr0600:t11dg): frdg
```

- Input password for workstation account at prompt.

```
331 Password required for frdg.
Password: password
```

- If not already in binary mode type 'binary' at prompt

```
ftp> binary
```

- Copy IEEE file using the *put* command at the ftp prompt, followed by Cray C90 IEEE filename and intended workstation filename.

```
ftp> put dump.ieee dump_file
```

- Exit from ftp using the *bye* command at the ftp prompt

```
ftp> bye
```

The transfer can also be initiated from the workstations by using the *get* command instead of the *put* command.

B.1.3 How to Transfer UM Fieldsfiles

There are a number of useful UNICOS and JCL routines for transferring data from the Cray C90 to COSMOS and on to the workstations. All the routines are set up to transfer the file scaab.pp4 from your home directory on the Cray C90, to MS15.XXSCAAB.PP4 on the COSMOS and thence to /data/stringyy/oneweek/frxx/scaab4.pp on the workstations. It is assumed throughout that your programmer letters are xx, your workstation account is on stringyy, your COSMOS prefix is MS15, your group is M11 and your TIC is zzzzz. Some or all of these will have to be changed before the routines can be used.

Transfers from the Cray C90 to COSMOS

The following job should be submitted to the Cray C90 (ISPF option N.R.1) after the model run is complete.

```
# QSUB -lT 60
# QSUB -lM 7Mw
# QSUB -q express
# QSUB -eo
#
echo "Release script, fpp0jls to output pp file"
UI=ruser=t11xx,racct='"(m11,xx,zzzzz)"'
cd $TMPDIR
cat >nlist <<EOF
 &PACK UNPACK=.FALSE.
 &END
 &TYPE OPER=.TRUE.
 &END
EOF
#Rick PROGRAM to copy UM PP output to vbs fieldsfile #####Rick next
FILENV=assign
export FILENV
#
#Set up default aliases.
#
RUNID=scaab
PP=4
CRAYFILE=$HOME/$RUNID.pp$PP
IBMFILE=ms15.xx$RUNID.pp$PP
echo "Cray file to copy " $CRAYFILE
echo "IBM file          " $IBMFILE
#
assign -a $CRAYFILE -s u fort.10
assign -a FFCOS1 -s cos fort.11
/u/um1/vn3.3/exec/qxfieldcos < nlist >outfc
vbstext='text="dcb=(lrecl=x,blksize=10000,recfm=vbs),unit=disk'
vbstext=$vbstext,'space=(cyl,(10,10),rlse)'
vbstext=$vbstext,'storclas=scdatprk,mgmtclas=mcsnc4"'
cat outfc
#### check fieldcos o/p in case no fields have been transferred #####
#### search on line .....THE VALUE OF NENT IS       0  (if no.=0)####
head outfc | grep NUMBER | cut -f3 -d"S" > outfc1
read <outfc1 NENTRIES
if test $NENTRIES -eq 0
then
echo "Number of fields is $NENTRIES so abort file transfer and o/p"
exit
fi
#### end of fields no. check                                      #####
putibm FFCOS1 $IBMFILE,stat=new,df=tb,$UI,$vbstext
CC=$?
if test $CC -ne 0
```

```
then
  echo " error in copy to vbs file on IBM "
  echo $vbstext
  exit $CC
fi
rm FFCOS1 jclfile nlist runlc runuc outfc*
#Rick ###end#############################################################
```

Transfers from COSMOS to Workstations

The following JCL should be submitted to COSMOS. It will then transfer the file MS15.XXSCAAB.PP4 to the workstations, creating the file /users/stringyy/oneweek/frxx/scaab4.pp. In the job card PROGRAMMER.XTN should be replaced with your own name and extension number, eg, LORRIMER.4829. Towards the end of the job, SER='05' should be replaced with the number of your own server.

```
//T11XXI2H JOB
(M11,XX,ZZZZZ),PROGRAMMER.XTN,PRTY=??,NOTIFY=T11XX,
// MSGCLASS=Q
//PROCLIB JCLLIB ORDER=(MS11.PROCLIB)
//*MAIN PROC=US
//*
//*
//* JOB TO TRANSFER A PP FILE TO HP
//* THIS JOB USES IN LINE PROCEDURE PPHPXFER TO TRANSFER
//* 64 WORD HEADERS
//*
//* Copied from ms14.cplib.cntl(pptohp)    15/5/93
//* New copy to copy to new FR div HP. PPHPXFER -> PPHPKFER
//* Copied from ms15.sm.utils(ibmhp)       19/4/94
//*
//*
//*MAIN PROC=US
//*
//C1   EXEC PPHP1,
//   DATASET=MS15.XXSCAAB.PP4,
//   STRING='stringyy',
//   TIMESPAN='oneweek',
//   FILENAME='scaab4.pp',
//   SPACE=(10,10),
//   JOBID=T11XXHP0,
//   HPUID='frxx',
//   TSOUID=T11XX,
//   PREFIX=MS15,
//   SER='05'
//*
//
```

Automatic Transfers

PP files can be transferred to COSMOS and/or the workstations automatically by inserting a script at the end of a UM run. The script is defined by going into the UMUI window **subindep_PostProc_ScrIns**

```
Sub-Model Independent
-> Post Processing
--> Top and bottom script inserts
```

Here the user must specify both a top and bottom script both of these must be resident on the machine on which the model is being run. The top script should just be a dummy script, the bottom script follows.

If transfers are required to COSMOS or an HP then IBMTR or HPTR respectively should be set to be true. This script uses getibm (see man page) to pull another script across. It is these which actually carry out the transfers. They are assumed to be in MS15.XXUM.JOBS. They are also given here, the last two of the following three scripts. As quoted here this job transfers scaab.pp4 to both the workstations and COSMOS and scaab.pp2 to COSMOS only.

```
HPTR=true
IBMTR=true
#
######### start of hp rel
if $HPTR
then
  echo "Release scripts fppthp to output pp files"
  cd $TMPDIR
  getibm "ms15.xxum.jobs(fppthp)" fpp
  CC=$?
  if test $CC -eq 0
  then
#
    PR=8
    PP=4
    ./fpp
#
  else
    echo " error in getibm fpp"
  fi
  rm fpp
fi
######## end of hp release
#
######## start of ibm release
if $IBMTR
then
  echo "Release scripts fpptibm to output pp files"
  cd $TMPDIR
  getibm "ms15.xxum.jobs(fpptibm)" fpp
  CC=$?
  if test $CC -eq 0
  then
#
    PP=4
    ./fpp
```

```
#
    PP=2
    ./fpp
#
 else
    echo " error in getibm fpp"
  fi
  rm fpp
fi
######## end of ibm release
```

The following script should be in MS15.XXUM.JOBS(FPPTHP).

```
echo "Release script fpp to output pp$PP file"
UI=ruser=t11xx,racct='"(m11,xx,zzzzz)"'
cd $TMPDIR
cat >nlist <<EOF
 &PACK UNPACK=.FALSE.
 &END
 &TYPE OPER=.FALSE.
 &END
EOF
#Rick PROGRAM to copy UM PP output to vbs fieldsfile #####Rick next
FILENV=assign
export FILENV
assign -a $DATAW/$RUNID.pp$PP -s u fort.10
assign -a FFCOS1 -s cos fort.11
$EXEC/qxfieldcos < nlist >outfc
vbstext='text="dcb=(lrecl=x,blksize=10000,recfm=vbs)'
vbstext=$vbstext,'storclas=scdatprk,mgmtclas=mcsnc4'
vbstext=$vbstext,'dataclas=dcdatvbs,space=(cyl,(180,60),rlse)"'
cat outfc
#### check fieldcos o/p in case no fields have been transferred #####
#### search on line .....THE VALUE OF NENT IS       0  (if no.=0)####
head outfc | grep NUMBER | cut -f3 -d"S" > outfc1
read <outfc1 NENTRIES
if test $NENTRIES -eq 0
then
echo "Number of fields is $NENTRIES so abort file transfer and c/p"
exit
fi
#### end of fields no. check                                        #####
putibm FFCOS1 ms15.sl$RUNID.pp$PP df=tb $vbstext
CC=$?
if test $CC -ne 0
then
  echo " error in copy to vbs file on IBM "
  echo $vbstext
  exit $CC
fi
#####Get lower case runid and convert to uppercase in RUNIDUC
```

```
cat >runlc <<EOF
$RUNID
EOF
tr abcdefghijklmnopqrstuvwxyz ABCDEFGHIJKLMNOPQRSTUVWXYZ <runlc >runuc
read <runuc RUNIDUC
#####Get current second to generate IBM job name so not identical
date '+%S' > date_second
read <date_second IBMNO
#####Generate dataset datename
date '+%d%m' > date_daymon
read <date_daymon DAYMON
########## IBM job ##############
cat >jclfile <<EOF
//T11XXH$IBMNO JOB (M11,XX,ZZZZZ),PROGRAMMER.XTN,
// PRTY=$PR,TIME=1,
// NOTIFY=T11XX,MSGCLASS=Q
//*
/*
//PROCLIB JCLLIB ORDER=(MS11.PROCLIB)
//  EXEC PPHP1,
//  DATASET=MS15.XX$RUNIDUC.PP$PP,
//  FILENAME='$RUNID$DAYMON.$PP',
//  SPACE=(10,10),
//  STRING='stringyy',
//  TIMESPAN='oneweek',
//  JOBID=T11XXH$IBMNO,
//  HPUID='frxx',
//  TSOUID=T11XX,
//  PREFIX=MS15,
//  SER='05'
//
EOF
echo "runid is $RUNIDUC"
ibmsub jclfile
CC=$?
if test $CC -eq 0
then
  echo " T11XXH$IBMNO job sent to IBM"
fi
  echo "condition code=$CC"
rm FFCOS1 jclfile nlist runlc runuc outfc*
#Rick ###end#############################################################
```

The next file should be placed in MS15.XXUM.JOBS(FPPTIBM).

```
echo "Release script fpp to output pp$PP file"
UI=ruser=t11xx,racct='"(m11,xx,zzzzz)"'
cd $TMPDIR
cat >nlist <<EOF
 &PACK UNPACK=.FALSE.
 &END
```

```
 &TYPE OPER=.FALSE.
 &END
EOF
#Rick PROGRAM to copy UM PP output to vbs fieldsfile #####Rick next
FILENV=assign
export FILENV
assign -a $DATAW/$RUNID.pp$PP -s u fort.10
assign -a FFCOS1 -s cos fort.11
$EXEC/qxfieldcos < nlist >outfc
vbstext='text="dcb=(lrecl=x,blksize=10000,recfm=vbs),unit=disk'
vbstext=$vbstext,'space=(cyl,(10,10),rlse)'
vbstext=$vbstext,'storclas=scdatprk,mgmtclas=mcsnc4"'
cat outfc
#### check fieldcos o/p in case no fields have been transferred #####
#### search on line .....THE VALUE OF NENT IS       0   (if no.=0)####
head outfc | grep NUMBER | cut -f3 -d"S" > outfc1
read <outfc1 NENTRIES
if test $NENTRIES -eq 0
then
echo "Number of fields is $NENTRIES so abort file transfer and o/p"
exit
fi
#### end of fields no. check                                        #####
putibm FFCOS1 ms15.xx$RUNID.pp$PP df=tb $vbstext
CC=$?
if test $CC -ne 0
then
  echo " error in copy to vbs file on IBM "
  echo $vbstext
  exit $CC
fi
  echo "condition code=$CC"
rm FFCOS1 nlist outfc*
#Rick ###end#############################################################
```

B.2 Operational Archives

Author: A. Van der Wal, Last Updated: 18 Mar 96

B.2.1 What's Available?

There seem to be so many different operational archives, that even the experienced user might be daunted by the task of retrieving model output. A full list is available from the COSMOS dataset cop.core.info(zarchive).

Three of the most useful archives are:

1. The WGDOS Packed Archive (see section B.2.2) - contains limited model output fields.
2. The WGDOS Fieldsfile Archive (see section B.2.3) - contains all model output fields.
3. The 18-Month Cray Archive (see section B.2.4) - contains initial analyses, acobs and boundary conditions which can be used for model reruns.

B.2.2 The WGDOS Packed Archive

This archive is provided by the *Working Group on the Development of the Operational Suite (WGDOS).* Details of the available fields are given in the following COSMOS datasets:

Model Type	COSMOS Dataset
UM Analysis	cop.wgdos.fields(umanal)
UM Background	cop.wgdos.fields(umback)
UM Forecast	cop.wgdos.fields(umfcst)
Main	cop.wgdos.fields(recm)
Update	cop.wgdos.fields(recu)
Fine Mesh	cop.wgdos.fields(recf)
Global Wave	cop.wgdos.fields(recg)
Lim. Wave	cop.wgdos.fields(rece)
Changes	mcf.wgdos.text(changes)

There are 3 formats which the model data can be restored to:

Fieldsfile: The file is of the same format as model output. This is a useful way of restoring data if its ultimate destination is the C-90.

PP format: This is probably the most useful form to restore archived data to, since the UKMO plotting facilities deal with files of this format.

VBS format: Try this format if you don't need a lot of data description (the header is short). See mcf.wgdos.cntl(painfo) for more details.

Technical information on the above options is available in UMDP F3 [23] or UMDP Y8 [31], or you may want to read more about diagnostic output (see section 3.16).

A Basic Example

Suppose you want to restore a week's worth of PMSL and H500 forecast fields (01/08/94 to 07/08/94, say), at T+0 and T+24, from a 00Z global forecast, and write them to a PP style dataset. The following is a step-by-step guide to do this:

1. Enter the WGDOS panels

Log on to COSMOS and type *tso wgdos* on the command line. If this doesn't work, try *tso exec 'mcf.master.clist(wgdos)'*. This will bring up the WGDOS title panel. Hit *Enter*, to give the main WGDOS menu.

2. Find the field type and level code

Choose *option 1 - WGDOS, option 1 - WGDOS* again, and then *option F - Fields*. Select the type of data you require ... in this example, it is *option 3 - UM Fcst*. This is a complete list of all the fields archived. In the first column, to the left of the field name, is a number. This is the *field type* and will be coded as *ITYP* in the extraction job. So, for pressure, *ITYP*=12 and for height, *ITYP*=2. Along the top of this table is a list of levels (coded as *LEV*), and an *X* indicates which levels are archived for a particular field. For height, the *A* beneath the *500* signifies that this field is also available at T+96 and T+120. Next to *pressure* there is an *A* in the column headed *8888* (indicating mean sea level), which means that there are 2 additional forecast times for this field too. We now know that *LEV*=8888 for pressure and *LEV*=500 for height.

3. Check for missing data

Before you go any further, it is imperitive that you check that the fields required are not missing. To do this, go back 2 panels, and choose *option M - Missing* followd by the type of fields you are interested in (*3* in this case). This list gives the dates and times of any fields which have been omitted from the archive, but be warned, it is not comprehensive. If you discover a field which is missing, but not on the list, let the archive manager know! Neither of the fields in this example are missing.

4. Look up cartridge details

The next step is to find out which cartridges contain the dates which you want to restore. From the top level menu, choose *option 3 - Extract2*. On this panel we would enter:

AGF for global forecast, *Y* for one month only, and then fill in the details of the month (MM=08, YY=94).

You will then be presented with a list of cartidge volumes and dataset names. Since these files are catalogued, you only need to remember the name, the last part of which tells you the first date that is on the tape. For the first week in August, we require 2 tapes, namely *cop.paagf.j940728* and *cop.paagf.j940804*.

5. Preparing the namelists

There are 2 namelists which are used to extract the fields from the archive.

- &DT
- &REST

The first defines the data time of the restore and the second defines the fields. See *option 4 - Examples* on the top level menu, and then *option 5 - Further Hints* for more details. In this example, we would set them up as follows:

```
&DT IZ=00,IU=21,PP=.TRUE.,ALL=.TRUE.  &END
&REST ITYP=2,ITIME=00,24,LEV=500  &END
&REST ITYP=12,ITIME=00,24,LEV=8888,LAST=.TRUE.  &END
```

There are some parameters which we haven't mentioned yet ...

- IU : the logical unit number attached to the output file in the JCL.
- ALL : specify as true if you want to restore all dates from a dataset. This is often quicker than specifying each date separately, if you want several dates from one tape.
- LAST : this should be set to true on the last *&REST* namelist.

6. Setting up the JCL

The restores are done on the IBM, so JCL is needed. Check out the example in WGDOS panel 4.2. You need a separate *EXEC* statement for each dataset you are trying to access. The final syntax for our restore job looks like this:

```
//M11AVRES JOB (M11,AV,RF19Z),NAME.EXT,PRTY=5,NOTIFY=T11AV,
//    MSGCLASS=Q,REGION=8000K
//*
//A1 EXEC PGM=PAREST
//GO.STEPLIB DD DSN=COP.PRODUCT.LOADLIB,DISP=SHR
//GO.FT05F001 DD *
 &DT IZ=00,IU=21,PP=.TRUE.,ALL=.TRUE. &END
 &REST ITYP=2,ITIME=00,24,LEV=500 &END
 &REST ITYP=12,ITIME=00,24,LEV=8888,LAST=.TRUE. &END
/*
//GO.FT06F001 DD SYSOUT=Q,DCB=(LRECL=133,BLKSIZE=133,RECFM=FBA)
//GO.FT21F001 DD DSN=MS15.AVTMP1,DISP=(NEW,CATLG),
//  STORCLAS=SCDATPRK,SPACE=(CYL,(2,1),RLSE),
//  DCB=(RECFM=VBS,BLKSIZE=15476)
//GO.FT81F001 DD DSN=COP.PAAGF.J940728,DISP=SHR,LABEL=(,,,IN)
//*
//A2 EXEC PGM=PAREST
//GO.STEPLIB DD DSN=COP.PRODUCT.LOADLIB,DISP=SHR
//GO.FT05F001 DD *
 &DT IZ=00,IU=21,PP=.TRUE.,ALL=.TRUE. &END
 &REST ITYP=2,ITIME=00,24,LEV=500 &END
 &REST ITYP=12,ITIME=00,24,LEV=8888,LAST=.TRUE. &END
/*
//GO.FT06F001 DD SYSOUT=Q,DCB=(LRECL=133,BLKSIZE=133,RECFM=FBA)
//GO.FT21F001 DD DSN=MS15.AVTMP2,DISP=(NEW,CATLG),
//  STORCLAS=SCDATPRK,SPACE=(CYL,(2,1),RLSE),
//  DCB=(RECFM=VBS,BLKSIZE=15476)
//GO.FT81F001 DD DSN=COP.PAAGF.J940804,DISP=SHR,LABEL=(,,,IN)
//
```

Retrieving fields is quite an expensive process, so it's best to use priority 5 whenever possible.

7. Useful contacts

Other people have been using this archive for a while, and may have already done the work that you are about to begin (e.g. forming monthly means). Here is a list of users who you might want to contact:

- John Prince (CC): responsible for the archive
- Dale Barker (NWP): has formed monthly means of humidity.
- Frank Saunders (CF): has formed monthly means of u, v, q and T.
- Anette Van der Wal (NWP): has formed monthly means of ppn, evap, surface fluxes (LH,SH,SW,LW), 1.5m temperatures and cloud (H,M,L,conv) (all forecast fields).

B.2.3 The WGDOS Fieldsfile Archive

This archive is basically a straight dump of fieldsfiles output from the UM. It contains all fields which are output operationally. See the COSMOS dataset cop.core.fflist to see what's available.

Depending on how much and what type of data you require, you may wish to use this archive. It is good for daily restores of fields not on the packed archive, but becomes expensive and time consuming if you want to restore data to form a monthly mean, say. Only 760 days worth of output is retained (on a rolling archive basis).

A Basic Example

Imagine the same example as in section B.2.2 above, but for just one day ... 01/08/94. Here's what to do:

1. Enter the WGDOS panels as in section B.2.2 above

2. Restore Data

Choose *option N - WGDNEW* to go into the "new" archive. Select *option 3 - Restore*, which will take you through a set of panels designed to generate the JCL required. Remember that it is the full model fieldsfile which is restored, which can use around 250 cylinders. In our example, we want the global 00Z fieldsfile, so we would enter the following:

```
OPERATIONAL RUN TIME ===> G00
DAY   ===> 01
MONTH   ===> 08
YEAR   ===> 94
RESTORE TO HI-LEV INDEX   ===> MS15
PROGRAMMER LETTERS   ===> AV
```

... then hit *Enter*. At the next panel, hit *Enter* again, to get a list of all fieldsfiles available, or just enter CFPROD.FFCLGM.ARCHQG00.FF940801. Type *sub* on the command line to move on. At this next panel, you should fill in your jobcard details. The JCL can then be stored and edited before submitting. It should look like this ...

```
//M11AVR01 JOB (M11,AV,FC02Z),DSM.FDR.RESTORE,REGION=4000K,PRTY=8,
//  NOTIFY=T11AV,MSGCLASS=Q,MSGLEVEL=(1,1),TIME=3
//*INFORM PRINTDATA
//JCL   JCLLIB  ORDER=(DSM.STORAGE.JCL)
//*
//* NEW WGDOS DIALOG GENERATED RESTORE JOB FROM USER ARCHIVE UABRF
//*
//TRY1   EXEC RESTORE
//RESTORE DD *
    SELECT DSN=CFPROD.FFCLGM.ARCHQG00.FF940801,NEWI=MS15.+AV,
           STORCLAS=SCDATPRK,PRESTAGE,COPY=1,NOTIFY=T11AV
/*
//
```

3. Extract required fields

You may already have a routine which extracts fields from a fieldsfile; it probably uses FFREAD. If not, then you can find out details of FFREAD and other access routines by selecting *option 5 - Access*.

Alternatively, Clive Jones has written a program which takes namelist input, to extract any number of fields. The namelist is called &FIND, and any of the pp header codes can be used to search for a field. In our example, the job would look like this ...

```
//M11AVR01 JOB (M11,AV,FC02Z),ANETTE.4098,REGION=4000K,PRTY=8,
//  NOTIFY=T11AV,MSGCLASS=Q,MSGLEVEL=(1,1),TIME=3
//*INFORM PRINTDATA
//JCL   JCLLIB  ORDER=(MS11.PROCLIB)
//*
//* JOB TO EXTRACT USER SPECIFIED FIELDS FROM A FIELDSFILE
//*
//EXTRACT EXEC PPP2G,OUTPUT=Q,BLK=,GOPGM=FFTOVAX,
//  LOADLIB='MS12.CJSSTLIB.LOADLIB'
//FT05F001 DD *
 &FIND MSFC=1,MSFT=0,SLEV=500 &END
 &FIND MSFC=8,MSFT=0,MSVC=128 &END
 &FIND MSFC=1,MSFT=24,SLEV=500 &END
 &FIND MSFC=8,MSFT=24,MSVC=128 &END
/*
//FT10F001 DD DSN=MS15.AVFIELDS.FILE,DISP=(SHR,PASS)
//FT11F001 DD DSN=MS15.AVNEW.DATASET,DISP=(NEW,CATLG),
//   STORCLAS=SCDATPRK,MGMTCLAS=MCSNC4
```

Note: The dataset MS15.AVFIELDS.FILE attached to unit 10 is the input dataset i.e. the one that has just been restored in step 2 above. The dataset MS15.AVNEW.DATASET is a new dataset which will be created, and will contain the fields you have extracted from the fieldsfile. It is important that you delete the fieldsfile as soon as you have finished with it as it uses a large amount of disk space.

B.2.4 The 18-Month Cray Archive

So, you want to do a model re-run? Well this is the place to retrieve your data from. The latest 18 months worth of analyses are stored for global, LAM and mesoscale models on a rolling archive. If you are running a case which is not on the archive, i.e. older than 18 months, then you will have to bring back the ECMWF analyses (see section B.3). The easiest way to set up a job to restore the data is to use the Observations User Interface (Obs UI, see UMDP U3 [29]) on COSMOS. This JCL can be stored and ammended for subsequent retrievals, although you are strongly advised to go back through the Obs UI panels, to ensure that the code is up to date, as developments are ongoing.

A Basic Example

Suppose you require analysis for a global 00Z re-run from 01/08/94. The following steps show you just how simple it is to restore such data:

1. Enter the Observations User Interface

Log on to COSMOS. If you are in CF, CR or NWP, then the Obs UI will be on your branch applications panel (as specified in UMDP U3 [29]). If you are in any other division then you will need to change a parameter on one of the COSMOS log on panels, which will enable you to access the NWP Division branch menu, and enter the Obs UI. On the 3rd log on panel (entitled: "Welcome to Time Sharing Option"), change the *PROCEDURE* to *M11LPROC*.

WARNING: By changing the *PROCEDURE* parameter, you may find that you are no longer able to access some applications specific to your branch. Once you have restored the required data, it is advisable to restart your COSMOS session, by logging off, and on again.

2. Create the JCL

Once you have gained access to the Obs UI, it is only a matter of filling in answers to the relevant questions. Firstly, choose *option 2 - Restore Datasets from the Cray Model Archive*, and then use the operational version of the panels. Once you have set up the JCL, you will be asked if you want to save it. It is a good idea to do so, since you will then have a reference point if a problem occurs. For our example, the JCL looks like this:

```
//M11AVRES JOB (M11,AV,RF19Z),NAME.EXT,
//    MSGCLASS=Q,NOTIFY=T11AV,PRTY=5
//*
//* Front End Job to restore datasets from Cray Model
//* Archive.
//*
//*INFORM PRINTDATA
//*
// EXEC PGM=FDRABR
//SYSPRINT DD SYSOUT=Q
//SYSPRIN1 DD SYSOUT=Q
//DISK1 DD UNIT=DISK,VOL=SER=TMP003,DISP=OLD
//TAPE1 DD UNIT=CART,DSN=COP.ARCHIVE.AM010894,
// DISP=OLD,LABEL=1
//ABRWORK DD UNIT=SYSDA,SPACE=(CYL,(1,1))
//SYSIN DD *
  RESTORE TYPE=ABR
  SELECT DSN=COP.ANALYSIS.GLM,TAPEDD=1,NVOL=TMP003,
  NEWN=MS15.AVANAL.QG00
/*
//*
// EXEC PGM=FDRABR
//SYSPRINT DD SYSOUT=Q
//SYSPRIN1 DD SYSOUT=Q
//DISK1 DD UNIT=DISK,VOL=SER=TMP003,DISP=OLD
//TAPE1 DD UNIT=CART,DSN=COP.ARCHIVE2.AM010894,
// DISP=OLD,LABEL=2
//ABRWORK DD UNIT=SYSDA,SPACE=(CYL,(1,1))
//SYSIN DD *
  RESTORE TYPE=ABR
/*
//
```

You will notice that the second *EXEC* step doesn't do any restores in this instance, and can be deleted if desired. It is used for restoring Mesoscale data and is present because these fields are kept on a different archive.

3. Top Tips

(i) The *NEWN* parameter is the dataset to which the restored data will be copied. Note that the Obs UI generates the same dataset name for restores of different dates, but similar field types. For instance, global 00z analysis for 01/08/94 will be copied to *MS15.AVANAL.QG00* (for me), as will global 00z analysis for any other date. Watch out for this, as trying to create a dataset which already exists will cause a failure.

(ii) Datsets created from this archive are **large**; it is best to transfer them to the Cray C90 asap, and remember to delete the copy on the IBM.

4. Useful Contacts

If you have any questions about the Obs UI, or if you are a first-time user, please contact Adam Maycock.

B.3 Obtaining Data from the ECMWF Archives

Author: Alan Dickinson, Last Updated: 22 Mar 96

B.3.1 The ECMWF MARS Archive

ECMWF store all of their observational, analysis and forecast data on a central file store. This archive contains operational and research data going back over ten years. A software interface known as MARS (Meteorological Archival and Retrieval System) provides a facility for accessing this data. Details on the contents of the ECMWF archive and how to use the MARS interface can be found in the MARS User Guide.

B.3.2 Running the UM from ECMWF Analyses

This section explains how to extract data from MARS, return the resulting file to the Met. Office's IBM and then convert this file into a format suitable for input to the Unified Model reconfiguration step. Only those programmers who have accounts on the ECMWF computer system can access MARS data.

ECMWF analyses may be obtained by running the following jobs for a programmer with an IBM userid of M99ZZ and a branch section number of 3 using an ECMWF userid xxx and password yyyyyy. The ISPF panel N.E.2 is used to submit the job.

```
#QSUB/USER="xxx"/PASSWORD="yyyyyy"
#QSUB/CPUTIME_REQ=60
#QSUB
set -xS
cd  TMPDIR
#
# Access MARS data under UNICOS
#
mars <<EOR
retrieve,type=an,levtype=sfc,levelist=off,
 repres=gg,date=901226,time=00,target="marsfile",
 param=st/sp/lsm/z,format=packed,grid=1.875/1.25,accuracy=normal.
retrieve,type=an,levtype=pl,
 levelist=all,
 repres=sh,date=901226,time=00,target="marsfile",param=t/u/v/r,
 format=packed,grid=1.875/1.25,accuracy=normal.
end
EOR
#
# Send MARS data down link to COSMOS
#
sendtm -lmarsfile -muk1 -fzz993data -eibm_classq_binary -dUS -aPF
```

The job accesses the pressure level archive at ECMWF via the Met. Office-ECMWF link and transfers the data back to IBM disk at the Met Office (dataset name MSS3.ZZDATA.PF in the above example, where SS is the branch identifier for user M99ZZ). The horizontal grid resolution and the analysis time and date may be changed via the parameters grid, time and date respectively. In addition, for dates prior to 15/7/86 where the surface geopotential is unavailable, param=st/msl/lsm must be coded for the surface field extraction.

If data on ECMWF hybrid vertical coordinates is required, then levtype=ml and param=t/u/v/q should be coded for upper air fields. Note that this option will not work if surface pressure and surface geopotential are not available.

Use the following commands, setting VN to the appropriate model version number:

```
VN=4.0
getibm 'mss3.zzdata.pf' gribfile1 df=bb
$UMDIR/vn$VN/exec/qxgribcon gribfile1 gribfile2
```

getibm transfers the file to the Met. Office Cray C90 and the utility **qxgribcon** formats the data ready to be read in by the reconfiguration step.

Acronyms

3DVAR: Three dimensional variational analysis (the next generation data assimilation system being developed to replace the analysis correction scheme)

ACOBS: Observation files used for the analysis correction data assimilation component of the UM

ADCP: Acoustic Doppler Current Profiler

AVHRR: Advanced Very High Resolution Radiometer

BUFR: Binary Universal Form for the Representation of meteorological data. It is a standard developed by WMO for the efficient storage of meteorological observations in a machine independent form, where all the information to describe the observations is contained within the data.

C90: Cray 90 Supercomputer

CFO: Central Forecasting Office

COSMOS: Front end computing system at the Met. Office, residing on an IBM mainframe computer, and separate from the HP workstation networks and Cray C90 supercomputer.

CR: Climate Research (Hadley Centre)

ELF: Equatorial Lat-long Fine-mesh

ECMWF: European Centre for Medium-Range Weather Forecasts

ERS: European Research Satellite

FOAM: Forecasting Ocean Atmosphere Model

FR: Forecasting Research (defunct), see NWP

FS: Forecasting Systems (old), see OS

GLOSS: Global locally-processed satellite soundings

GRIB: WMO standard for GRIdded Binary data. It is designed to provide efficient storage on data on a variety of grids

HP: Hewlett Packard. Brand of workstation currently used at the Met. Office.

JCL: Job Control Language (IBM)

JCMM: Joint Centre for Mesoscale Meteorology

LAM: Limited Area Model

LASS: Local Area Sounding System

MARS: Meteorological Archival and Retrieval System

MES: Mesoscale Model

MetDB: Meteorological Data Base (of observations prior to processing for the UM)

MLD: Mixed Layer Depth

MOPS: Moisture Observation Pre-processing System

MPP: Massively Parallel Processors

MSL: Mean Sea Level

MSLP: Mean Sea Level Pressure (see PMSL)

MVS: Multi Virtual Storage IBM mainframe operating system - in use at the Met. Office since 1979

NOAA: National Oceanic and Atmospheric Administration

NWP: Numerical Weather Prediction

OPS: Observation Processing System

OS: Operational Services

PL: Programmer Letters

PMSL: Pressure at Mean Sea Level

SST: Sea Surface Temperature

STASH: Spatial and Temporal Averaging and Storage Handling (storage handling and diagnostic system)

TKE: Turbulent Kinetic Energy

TIC: Task Identification Code (for administrative accounting)

UARS: Upper Atmosphere Research Satellite

UI: User Interface

UKMO: United Kingdom Meteorological Office

UM: Unified Model

UMACS: Unified Model Analysis Correction Scheme

UMDP: Unified Model Documentation Paper

UMUI: Unified Model User Interface

WBPT: Wetbulb Potential Temperature

WGDOS: Working Group on the Development of the Operational Suite

WGDUM: Working Group on Development of the Model

WMO: World Meteorological Organisation

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